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PAPER No. 1079.

WIRELESS TELEGRAPHY AND TELEPHONY.

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(Active Member.)

Read November 21, 1908. *Revised December*, 1909.

THIS paper is a brief review of the art commonly known as "wireless telegraphy"; and deals with only one branch of the general subject, that is, with wireless telegraphy and wireless telephony which employ as the energy transmitted through space from the sending to the receiving station what are commonly known as "Hertzian oscillations" or "Hertzian waves," or "electro-magnetic waves," all being synonymous.

There are other systems of wireless telegraphy and telephony which will not be considered, because, so far as the author knows, they have not come into any extensive commercial or general use; that is, the "earth shunt" and simple "induction" systems.

Had this paper been written ten years ago, it might well have gone into greater detail than will be the case now, because at that time the art was quite restricted as compared with the present time.

Fundamentally, wireless telegraphy and telephony depend upon a wave propagation through the ether, the energy having electric and magnetic components, and with a frequency so high as compared with ordinary alternating currents as to denote the energy as "high-

frequency waves or oscillations." To give an idea as to the position in the whole category of ether waves of those employed in wireless telegraphy and telephony, the following is submitted:

X-Rays—not visible to human eye; ultra-violet light; frequency 870 trillions to 1500 trillions per second.

Light—visible to human eye; frequency 430 trillions to 740 trillions per second, less than one octave.

Infra red—invisible; frequency 430 trillions down to 300 trillions per second.

Heat—frequency 300 trillions down to 20 trillions per second.

Electro-magnetic waves (Hertzian waves or oscillations)—forty-five octaves lower; frequency of several millions per second down to 100,000 or less per second; used in wireless telegraphy and telephony; 300 feet (or less) to 5000 feet (or more) in length.

Sound waves (audible to human ear); frequency of 40,000 per second down to 32 or 16 per second.

From this table it will be seen that the waves used in wireless telegraphy and telephony have a frequency much lower than light waves, and, indeed, far lower even than heat waves, being just above sound waves in the table. And it will be understood that the frequencies under consideration range from about a million per second to one hundred thousand, or less, per second.

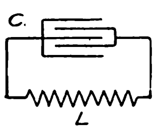


Fig. 1.

The earliest known way of producing high-frequency electric waves, and the way that is in common use, consists in letting loose through a sufficiently low resistance path a charge of electricity, which, when the resistance of the discharge path is sufficiently low, oscillates or swings electrically like a pendulum, there being a decrement in the amplitudes of the successive waves causing them to die out sooner or later, as a pendulum will come to rest after a time.

To consider an elemental case, refer to Fig. 1. Consider the condenser C connected in circuit with the inductance L. The condenser, as is well known, consists of two conducting plates or armatures separated by a dielectric medium, as air, gas, or what not. The inductance consists of a coil of wire, for example (preferably without iron core for high-frequency work), and is a means for lending magnetic inertia to the circuit. If the condenser C has been charged

from any suitable source of electricity, it will discharge through the circuit containing itself and the inductance L. The charge will swing first one way and then the other, back and forth, at high rate, gradually dying out owing to radiation of energy from the circuit and owing to resistance and other losses in the circuit.

The frequency of the oscillations so produced is dependent upon the capacity of the condenser C, the magnitude of the inductance L, and the resistance of the circuit. The resistance of the circuit should be made as low as possible consistent with other requirements; and when below a certain critical value oscillations take place, and when the resistance is made low, it may be disregarded as a factor in the determination of the natural frequency of the circuit.

The natural frequency of the circuit may then be expressed as follows:

$$N = \frac{1}{2\pi\sqrt{LC}}$$

N being the number of complete cycles per second, L the inductance, and C the capacity of the circuit. It is evident that N will be greater as either L or C, or both, is or are smaller. This shows algebraically that for high-frequency work inductances and capacities employed are quite small as compared with those used in ordinary alternating-current commercial work.

The speed or velocity of propagation of the energy of Hertzian or electro-magnetic waves through space is the same as that of light, namely, 186,000 miles per second. Knowing this, and knowing also the frequency, N, the wave length is easily computed from the expression

$$V = N\lambda$$

where V is the velocity of propagation, N the frequency, and λ the wave length.

The high-frequency oscillations may be graphically represented as in Fig. 2. Distances measured horizontally represent time, while those measured vertically represent amplitude or intensity. The upper part of the figure illustrates a slightly damped train of waves or oscillations, and are such as may be produced by what is termed a resonator. In the lower half of the figure is shown a train of strongly damped oscillations which die out very quickly. Such oscillations exist in a good radiator, it being characteristic of a resonator or

sustained oscillator that radiation of energy into space may be slight, while in the case of strongly damped oscillations the radiation may be relatively great; or, to put it another way, when radiation is efficient and great, the oscillations are relatively strongly damped.

In wireless telegraphy, particularly in the spark systems, good radiation is desirable, as also is persistency of the oscillations, so that we have opposed conditions to be met. Persistent oscillations make it easier for "tuning" the distant receiving apparatus, while good radiation means that the energy can penetrate to a greater distance.

Coming now to something more concrete, Fig. 3 represents the Hertz oscillator or transmitter.

Heinrich Hertz was the first to profoundly investigate the subject

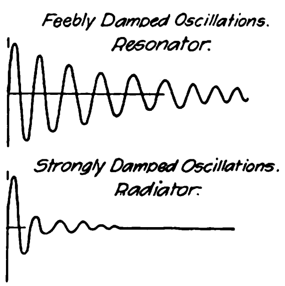


FIG. 2.

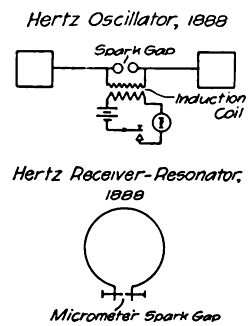


FIG. 3.

of high-frequency electric waves or oscillations. In 1888, or thereabouts, as professor at the University of Bonn, in Germany, he constructed such an oscillator. It consists of two conducting plates, here shown rectangular, each connected to a ball or other spark gap terminal, the balls being separated a short distance to form the spark gap. The secondary winding of an ordinary induction or Ruhmkorff coil has its terminals connected to the spark gap terminals, while in the primary winding of the induction coil is included a battery or other source of energy, suitable interrupter, and a switch or key. The secondary of the coil delivers high-potential current, thus charging one of the capacity areas positively and the other negatively. When their potential rises sufficiently high, a spark leaps across the spark gap, forming an instantaneous circuit closer or bridge over which the electric charge oscillates or vibrates at an extremely high

rate. By opening and closing the switch or key the sparking is stopped or started.

His receiver is shown in the lower portion of the figure. It is known as a resonator and consists of a loop of wire having its ends separated by a micrometer spark gap. He chose the product of the capacity and inductance of the loop to conform suitably with the product of the capacity and inductance of the separated plates and their connections in the oscillator, and upon the passage of a spark at the spark gap of the oscillator there was a passage of a minute spark at the micrometer gap of the receiver or resonator.

This was then a complete wireless telegraph apparatus, though in the form shown was not suitable for very long distance work.

Because of the form of the oscillator, having large separated areas connected by a slender conductor, it has been termed the "dumb-bell" oscillator.

So to speak, Hertz set his electric pendulum, the oscillator, into vibration, and his loop or resonator being in electric sympathy with it, tuned to the frequency of his pendulum, his receiver responded efficiently to the frequency of the transmitter and caused the spark at the micrometer gap.

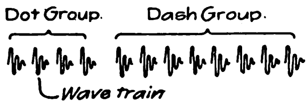


Fig. 4.

For every impulse of high-potential current from the secondary of the induction coil there was a spark at the gap of the oscillator or transmitter, and for each of those sparks there was generated a "train" or "group" of high-frequency oscillations or waves.

This may be illustrated by Fig. 4.

To represent a "dot" in wireless telegraphy a few wave trains or wave groups succeed each other, while for a "dash" a greater number of wave trains or groups succeed each other, this being determined by the length of time the key or switch in the primary of the induction coil is held closed.

Coming now to the original Marconi transmitter, illustrated in Fig. 5, we have in the left-hand view an aërial conductor or antenna, as it is indifferently called, consisting of a wire or conductor extending upward above the earth's surface and having its lower end connected to a spark gap terminal, the other spark gap terminal connected to earth, the secondary of an induction coil connected to the spark gap terminals and the primary including the source of energy, key, and interrupter. You will at once see that this is precisely the Hertz

oscillator of Fig. 3, the aërial conductor or antenna of Fig. 5 representing one of the capacity areas of Hertz's oscillator, while the earth is the other. Here the oscillations are produced in the aërial conductor or antenna and are radiated from it in all directions, as light from a candle. It has been found that where the oscillations are generated in the aërial conductor itself the length of the aërial conductor is equal to one-fourth the length of the wave generated in it. Thus, if the aërial conductor is 150 feet long, the length of the wave generated in it and radiated from it is 600 feet. Such an aërial conductor, having relatively small inductance, is a good radiator, the oscillations being capable of dying out quite rapidly owing to the radiation of energy into the surrounding medium.

In the next to the right-hand view is shown an inductive coupling, the high-frequency oscillations being produced in a circuit including

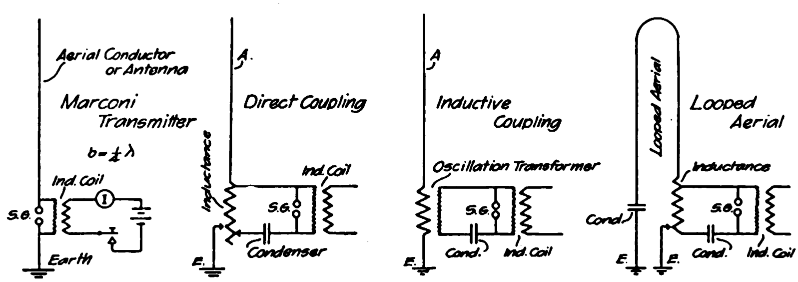


FIG. 5.

the spark gap s g, the condenser and the primary of an oscillation transformer, the secondary of the oscillation transformer being connected in series between the aërial conductor and earth. This makes a very good transmitter; the frequency of the radiated energy may be very closely determined and controlled and the oscillations are not generated or produced in the aërial conductor, but are forced thereon through the medium of the oscillation transformer. So that here the antenna does not entirely determine the frequency or wave length of the radiated energy. However, if the oscillation circuit, including the condenser, spark gap, and primary oscillation transformer, has a natural frequency which is relatively low, and the length of the antenna is far below one-quarter of the wave length corresponding to the oscillations in the condenser circuit, the antenna will not be radiating to the best advantage. This condition

of affairs is often met in the matters of contract with the Government where, with a given output of the current generator at the transmitter, a great range in wave lengths radiated is required. To store in the condenser the full output of the generating apparatus the condenser must be relatively large. Yet when the condenser is of relatively great capacity it reduces the frequency and, therefore, increases the wave length of the oscillations in the condenser circuit. And this, in turn, means that a given aërial conductor will be too short to efficiently radiate the low-frequency energy, while at the higher frequencies it would efficiently radiate. And if it be attempted to crowd matters by raising voltage, the antenna delivers a brush discharge, the excess energy which it cannot radiate being so dissipated into the immediately surrounding atmosphere.

In the next to the left-hand figure is shown a direct coupling with a closed oscillation circuit. Here the part of the variable inductance

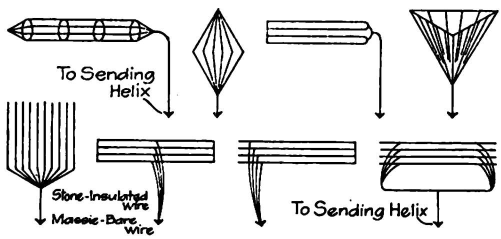


Fig. 6.

connected between the radiating or aërial conductor and earth is also common to the closed oscillation circuit, including the spark gap s g and the condenser. This makes an excellent transmitter, and by adjusting the amounts of inductance in the aërial and in the condenser circuit the aërial path may be brought into tune or resonance with the closed oscillation circuit.

In the right-hand view is shown a looped aërial conductor which is not insulated at the top, but has its top connected to earth. The connection between the condenser or oscillation circuit and the aërial conductor is a direct coupling, as in the next to the left-hand view.

These views of Fig. 5 represent elementally some of the better known and more useful transmitters as used to-day, though the early Marconi transmitter is seldom, if ever, used, except perhaps by amateurs or for very short transmissions.

In Fig. 6 are shown elementally different constructions of aërial

conductors without regard to the form or type of oscillation producer used in connection therewith.

In the upper left-hand corner is shown a wire cage located at the top of the aërial conductor, either horizontally or in any other position, which gives added capacity at the top of the conductor. The next below shows also a multiple arrangement of wires at the top. The one next shows a plurality of wires extending vertically and having a common connection at the bottom to the sending apparatus. The one in the lower right-hand corner shows a plurality of horizontally disposed wires at the top, connected in parallel with each other and connected together at the bottom to the sending apparatus. There is shown also a spread-out antenna of a plurality of wires in diamond shape; and also an inverted three-sided pyramid arrangement. Next below is a plurality of multiple horizontal wires connected together from their centers to sending apparatus. And there is shown a plurality of horizontal wires at the top having several separated connections coming to a common connection downward to the sending apparatus.

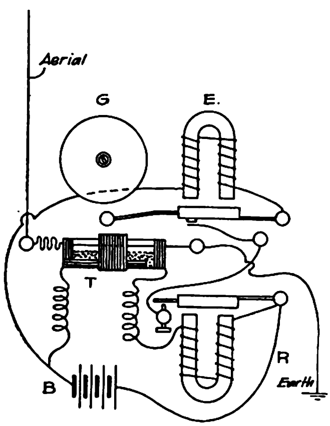


FIG. 7.

While Fig. 6 illustrates numerous forms of spread-out aërials or antennas, it has been found good practice also to have the aërial conductor composed of a plurality of wires which are closely bunched instead of being spread out. With a spread-out arrangement, if the spread is any considerable fraction of the wave length, each conductor sends out its wave, and there results a combination of dephased waves in space, which is a disadvantage in most cases to the receiving apparatus.

Coming now to receiving apparatus, probably the first practical wireless telegraph receiver was devised by Popoff, of the Russian navy, who in 1895 devised the apparatus shown in Fig. 7. This apparatus was devised for recording and predicting lightning storms, some recorded being at such distance that at the location of the recording apparatus it was not otherwise known that a lightning storm existed. The flash of lightning produced became a natural spark gap or natural producer of oscillations, and these oscillations were picked up on an

aërial wire whose lower terminal was connected to one terminal of the filings tube or coherer T, the other terminal being connected to earth. The coherer or filings tube T comprised separated terminals within a glass tube, between and in contact with which was placed a mass of iron or other metal filings. Such a device, as found in 1892 by Branley, was sensitive to electric waves or high-frequency oscillations. The device normally has a very high resistance, but upon high-frequency oscillations traversing the device the filings drop enormously in resistance (the resistance reduction is used to produce the signal) and remain in the condition of low resistance until mechanically shocked, when they again resume the high-resistance state. The action has been explained as one of cohesion, and, therefore, the device has been termed a "coherer." And though detectors or wave-responsive devices coming later in the art did not comprise filings or anything like them, the term "coherer" became for a long period a general one to denote all types of wireless detectors. Popoff connected in series with the filings tube the battery B and the relay R, the relay controlling also a local circuit including the winding of an electric bell magnet E, the hammer being used to strike the tube, to automatically restore the tube to sensitive condition. Popoff's arrangement was, in fact, a perfectly practical wireless telegraph receiver.

Later, Marconi used almost identically this arrangement as his receiving apparatus in connection with the transmitting apparatus shown to the left in Fig. 5.

Coming now to later forms of the receiving apparatus, and such as may be taken as fairly representative of types, without going into great detail, Fig. 8 shows in the left-hand figure a non-tuned receiver having an open aërial conductor, between which and earth is connected a detector comprising carbon filaments resting on steel knife-edges, and in a local circuit is included a telephone and a battery. At each spark at the distant transmitting apparatus a train of waves is radiated into space, and these waves impinge upon the aërial conductor, setting up therein minute high-frequency currents or oscillations which surge up and down in the conductor through the detector or oscillation-sensitive device, causing it to change its condition suddenly, to thereby cause increased or decreased current through the telephone, producing therein a click, such click corresponding with the spark at the distant station. Several clicks coming close together indicate a dot, and a longer series of clicks indicates a

dash. This has been called a non-tuned receiver, though it may be roughly tuned to the transmitting apparatus if the dimensions and disposition of the aërial conductor are similar to those of the aërial conductor of the transmitting apparatus.

In the middle sketch is shown a tuned receiver having an aërial conductor, between which and earth are connected the variable inductance and variable condenser. In shunt to the condenser is connected the detector or sensitive device, and in shunt to it is connected a telephone receiver and battery. To get the receiving apparatus into tune the condenser or inductance, or both, is or are suitably varied.

In the right-hand sketch is shown a looped aërial conductor with

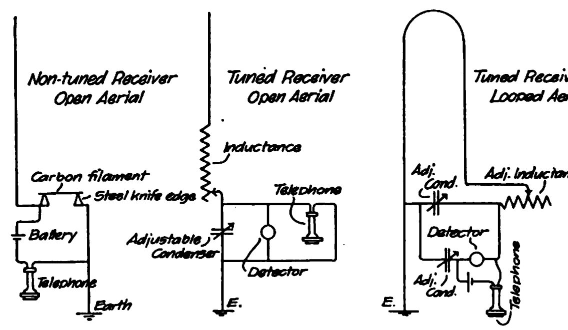


Fig. 8.

tuning apparatus, the latter comprising an adjustable inductance and an adjustable condenser.

An important element of each wireless telegraph set is the detector or sensitive device at the receiving station. A good detector, one which is very sensitive yet rugged, and not likely to get out of order, is an important factor in satisfactory wireless telegraphy and telephony. But even with the best of detectors, if the transmitting apparatus is not of the best form or type, or if the receiving circuits independent of the detector are not of the best form or type, successful communication cannot be had.

In Fig. 9 are illustrated several forms of detectors.

It will be recalled that the filings coherer had to be tapped to restore it to sensitiveness ready to respond to the next train of received waves or oscillations. It was not, therefore, a self-restoring detector or receiver. The receivers or detectors of Fig. 10 are all

self-restoring; that is, immediately after response has been made to a received wave train, it restores itself, or automatically returns to sensitive condition ready to respond to the next train of arriving waves. All the detectors shown in this figure are of the liquid type; that is, they comprise two terminals bridged in one form or another by liquid.

In the upper left-hand corner is shown the Pupin detector of 1899, due to Professor Pupin of Columbia University, who used it to detect Hertzian oscillations, just such oscillations as are used in wireless telegraphy. The action was, as he believed, a rectification of the Hertz waves, more or less complete. The high-frequency alternating currents or Hertzian waves or oscillations were believed to act upon the cell with its adjuncts in such fashion that the oscillations were

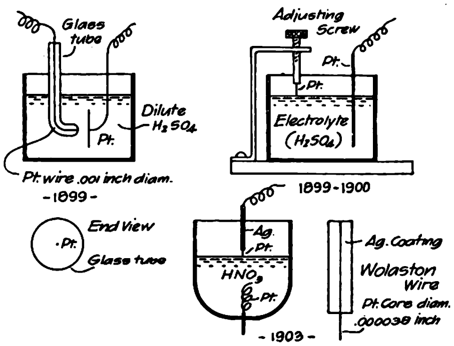


FIG. 9.

more or less rectified. But, whatever the action, the result was that an indicating instrument gave a decided indication at each spark of the transmitter, or, what is the same thing, for each train of waves generated and received. This detector consists of a mass of dilute sulphuric acid in which dips a terminal of platinum, wire or plate. The other terminal is a platinum wire, 1 mil. (0.001 inch) in diameter, sealed in a glass tube, the platinum wire being polished or ground off flush with the end of the glass so that only the cross-sectional area of the end of the glass is exposed to the solution. This small area is separated in the sulphuric acid from the other and larger platinum terminal. This is, indeed, a sensitive detector, and the author has himself successfully employed it in Philadelphia at the wireless telegraph station on the Bellevue-Stratford Hotel; and with-

out any effort at tuning has received distinct and loud messages from New York and Washington. And with crude tuning apparatus, which is necessary with even the best of detectors, it was possible to pick up messages from very much greater distances. Indeed, so far as the author knows, the Pupin detector is about as good, all matters considered, as exists to-day.

The Pupin detector, exactly as shown in the figure, has been used with marked success in the United States navy.

At the upper right-hand corner of Fig. 9 is shown a very similar detector due to Captain Ferrié of the French army. In 1899 and 1900 he successfully used this detector, platinum and platinum in dilute sulphuric acid, in transmitting messages between the different army stations or forts around Paris, as Captain Ferrié himself told

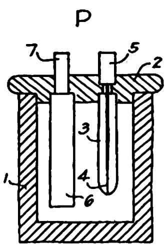


Fig. 10.

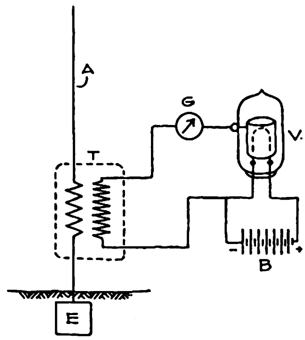


Fig. 11.

me. Like the previous detector, it is self-restoring, and it is, indeed, the same in principle.

Later, in this country, there was evolved the Wollaston wire form, using one large platinum terminal in nitric acid, and as the other terminal the platinum core of a Wollaston wire projecting into the acid. The platinum core is extremely fine, being only about 0.00004 inch in diameter—a microscopic wire. This produces a very sensitive detector, but is not as rugged as the Pupin form, where the wire is inclosed in glass and is not so easily destroyed. The Pupin arrangement is "fool proof," while the Wollaston wire type is much more delicate and probably more sensitive.

In Fig. 10 is shown still another form of self-restoring detector, consisting of the Pupin glass tube, 3, with the small platinum wire, 4, sealed in and ground off flush with the glass. This dips into dilute

sulphuric acid or other cell excitant contained in the jar or vessel, 1, the other element being a plate or bar, 6, of zinc or other metal or conductor other than platinum. This device having dissimilar metals thus constitutes a primary cell, and it is known as the primary cell detector. It is very sensitive and, like the Pupin device, is "fool proof." The telephone is connected directly to the terminals 5 and 7; no local battery is employed.

In Fig. 11 is shown a curious type of detector accredited to Professor Fleming, of England. It is called a "valve tube," and consists of an exhausted bulb, V, similar to an incandescent lamp bulb, in which is a carbon or other filament, shown in dotted lines. Surrounding this is a metallic cylinder, as of platinum. In circuit with the carbon filament is a source of energy, B, to keep it incandescent. The oscillations delivered from the secondary of the oscillation transformer, T, pass through the indicating instrument, G, to the plate in the vicinity of the heated carbon filament; the heated carbon filament forms the other terminal of the detector. This device is said to be a rectifier, causing the high-frequency current waves or oscillations to be rectified to give an indication in the instrument, G, which may be a telephone.

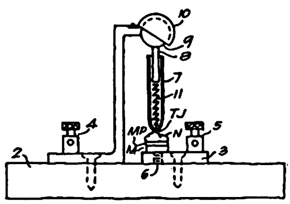


FIG. 12.

A detector resembling the Fleming detector is called the "Audion." Both of these detectors are self-restoring. A carbon filament within an evacuated bulb is kept hot or at incandescence by the source of energy or a battery. The carbon filament forms one terminal of the detector, being connected to earth, while the other terminal within the bulb is of platinum or other suitable material, and connects with the receiving circuit. In the local circuit is a battery and relay, telephone or other instrument. Rectification probably occurs here also. But it is immaterial what the process may be in any detector; the fact is always that the received oscillations produce a change in or by the detector, which change is noted in the telephone and read by the operator. Whether the action of a detector be rectification, resistance change, depolarization, or what not, is a matter of extreme indifference from the commercial and practical standpoint, inasmuch as whichever of these or other processes may occur, the

result is the same in that the operator hears a click in his telephone for each spark at the transmitting station.

In Fig. 12 is illustrated a late development in wireless detectors. It is known as the "silicon" receiver and is accredited to Mr. Pickard. The silicon used is not a compound of silicon, but simply silicon, which is a black mass capable of taking a polish. The mass of silicon, N, is engaged by a brass or other conducting finger or rod, spring pressed. The silicon and the engaging conductor form a thermo-electric couple capable of producing a small electric current when heated. The faint high-frequency electric currents, due to the electric waves transmitted through space, pass through the thermo-junction, heating the same, and the couple then produces a current passed through the telephone or other instrument, causing a click or sound in it. Here again is a detector which requires no

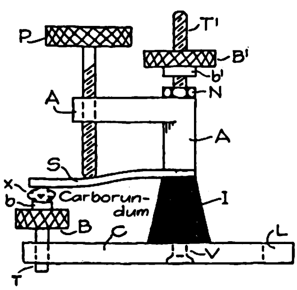


Fig. 13.

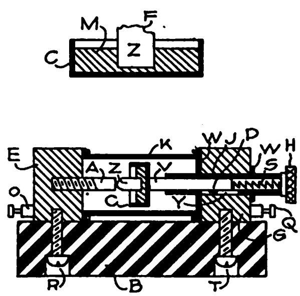


Fig. 14.

local battery, a thing which was conspicuously necessary with the earlier detectors; also with the Pupin and Fessenden or Vreeland detectors. The silicon detector is also considered as a solid rectifying device. It is the actual energy of the faint high-frequency currents that is rectified and made to produce the click in the telephone receiver. This silicon detector may also be used in connection with a local circuit having a battery and telephone.

The carborundum detector is shown in Fig. 13. This may work without a battery in the local circuit, but ordinarily a local battery is used. A carborundum crystal, X, is held resiliently against a conductor, b. The carborundum used is secured by selecting a suitable crystal from a mass of carborundum such as is made at Niagara Falls in the electric furnaces. By exercising sufficient care

in the selection and mounting of the crystal an extremely sensitive self-restoring detector is produced.

Indeed, many crystalline substances serve for wireless telegraph detectors. Experimenters are finding out that very many crystalline substances have the property of responding to electrical waves to some degree or other.

In Fig. 14 is represented what the author believes to be one of the best and most sensitive detectors of the present day. This is also due to Mr. Pickard, and is known as the "Pericon" detector. It is self-restoring and requires no local battery, as in the case of the silicon detector. In engagement with a mass of fused zinc oxide, Z,

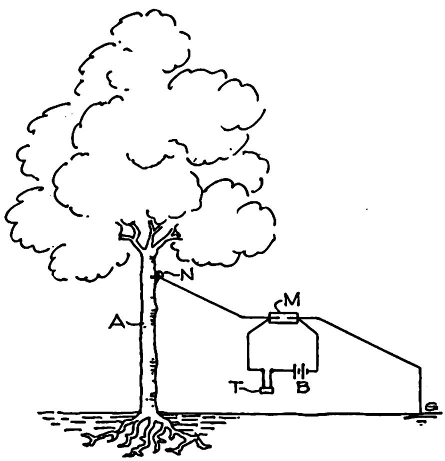


FIG. 15.

is a metallic or other conductor, A. Zinc oxide is fused, preferably in an electric arc, and when cool a piece is fractured to produce a sharp edge or roughened surface for the engagement of the conductor, A, or the natural mineral may be used.

While different types of detectors have been shown, some connected in certain types of receiving circuits or arrangements, it must be understood that different detectors may each be used in various different circuit arrangements and connections. A detector, in general, does not require any particular arrangement of circuits or mode of connection, but some modes of connection are more effective than others.

It may be interesting to know that the usual aërial conductor or

antenna, with its necessary mast or other means of support, is not always required, though it is required for best operation. It has been found, as shown in Fig. 15, that a living tree may be used as a means for collecting high-frequency energy from the ether. A spike may be driven in the tree near the top and connected through the

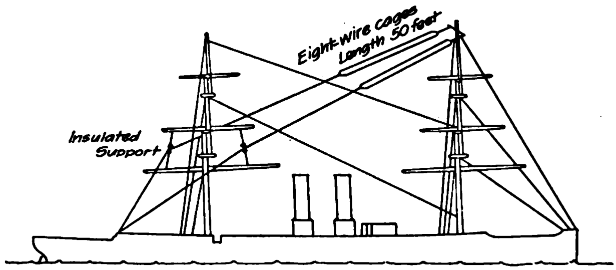


FIG. 16.

detector, M, to the earth, the usual local circuit with battery, B, and telephone, T, being provided. This arrangement, the author understands, works quite satisfactorily, especially for emergency work, and a tree may be used as a part of a transmitting apparatus.

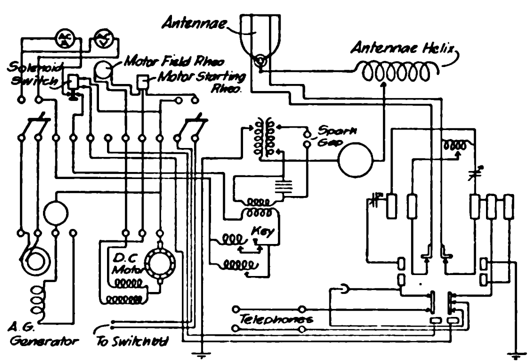


FIG. 17.

In Fig. 16 is shown the aërial conductor arrangement of the United States ship "Topeka"; some of the wire cages, previously referred to, are insulated at the mast head and at other places, with leads to the operating room near the stern of the vessel. At the extreme top between the cages there is a small spark gap, which during the trans-

mission of messages equalizes the potential on the two cages and their connecting wires.

Fig. 17 is a diagrammatic view of the circuit connections of a complete wireless telegraph receiving and transmitting outfit as installed on United States ship "Maryland." The direct current motor is driven off of the ship's circuit, an automatic starting box being provided. The motor drives an alternating-current generator at suitable speed to get the desired primary frequency. The energy from the alternator is used in the primary of the step-up transformer, the secondary supplying a closed oscillation circuit, inductance, spark gap, and condenser. The antenna has an anchor spark gap at the bottom so that the two halves of the antenna may operate in common in transmitting and independently in receiving. These matters of ship and other installations have now reached an engineering stage and the different control parts, instruments, etc., are mounted on a switchboard.

Fig. 17A shows this same system as installed in the operating room of the United States ship "Maryland." On the table in the corner are recognized the Leyden jars forming the oscillation circuit condenser. On top of it is the helix forming the inductance of the oscillation circuit. With its axis horizontal and at the top of the room is shown the antenna helix for effectively lengthening the antenna. On the small box on the table is shown the primary cell detector with switching apparatus, and upon the table is also seen the head telephone for the operator, comprising a watch-case receiver for each ear, the two receivers being connected by a band for holding them upon the operator's head.

The antenna helix near the top of the operating room is like the one in Fig. 17. It is a coil of bare wire upon a suitable frame, and the same frame carries on one side a hot wire ammeter which measures the amount of current flowing up the antenna. It may seem strange that an open-ended wire, like an antenna, can receive a current; but such is the case, and by a hot wire ammeter the amount is indicated. The ammeter is used not merely to satisfy curiosity as to the amount of energy going up the antenna, but is a means for knowing when the inductance in the aërial path and the inductance in the condenser circuit are properly correlated for maximum effect. When these inductances are properly correlated a maximum of energy will flow up the antenna.

With the rapid advance of this art, and with its reaching an en-

gineering stage requiring the subject to be reduced to an exact science, there has sprung up a necessity for a frequency or wave meter for these high frequencies used.

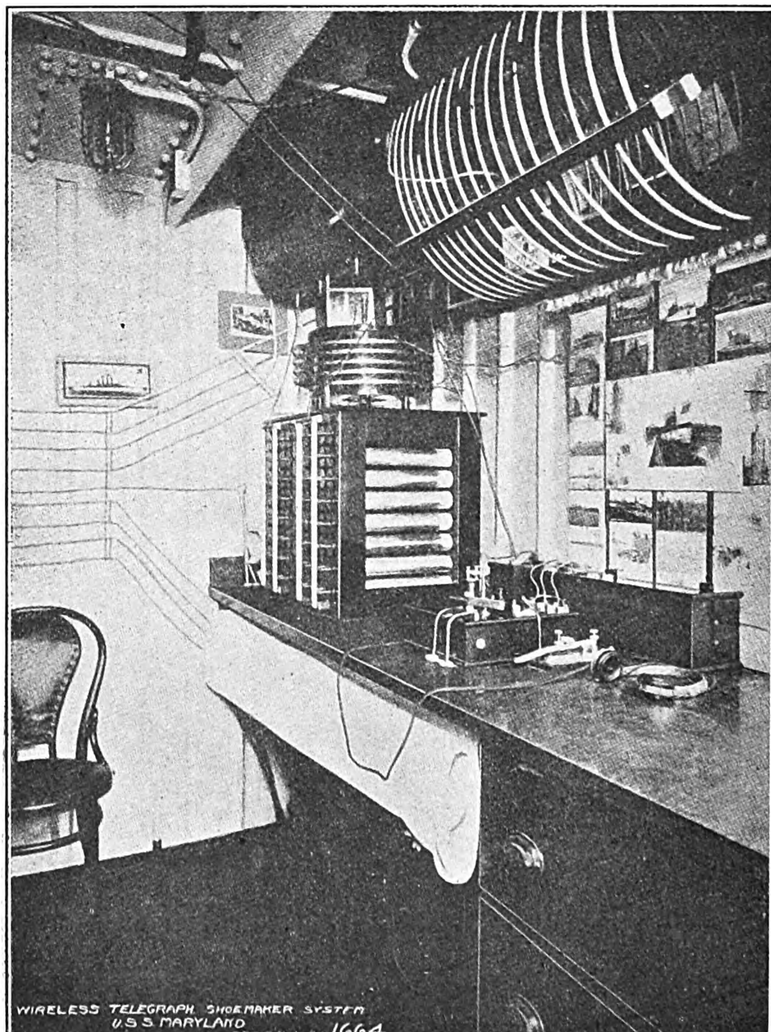


FIG. 17A.

Such a wave meter is shown in Fig. 18. Within the box is an adjustable condenser whose armatures comprise a series of stationary

plates within which may interleave a series of movable plates, of course without contact, the dielectric being air. By rotating the movable plates by the handle, carrying a pointer, the amount of capacity is adjusted. In circuit with the condenser is an inductance, shown in the coil supported upon the end of the box.

Suppose you have a transmitting apparatus whose frequency or wave length you wish to determine. You hold this portable instrument within the range of influence of the transmitting apparatus, but without any connecting wires. You then adjust the condenser

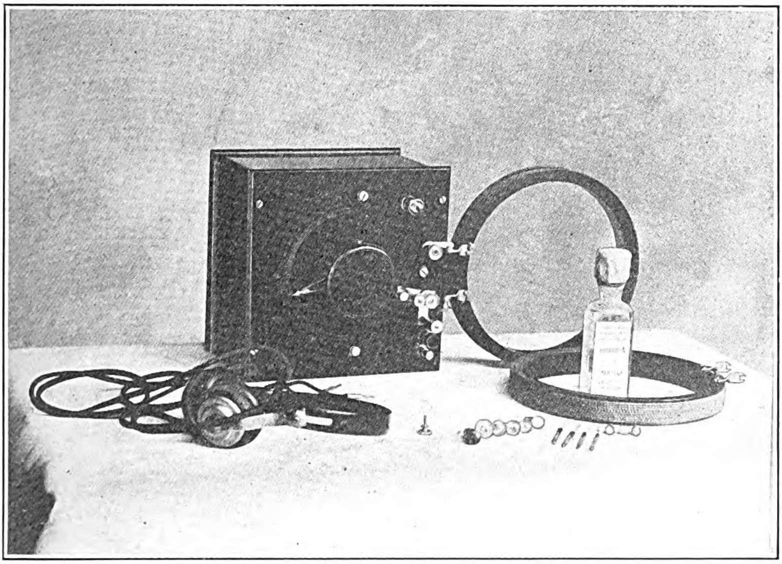


FIG. 18.

and move the pointer over the scale. A small detector, such as the primary cell detector above described, is connected across the terminals of the condenser or the inductance and in shunt with it is connected the telephone shown upon the table. When the needle is on that point of the scale corresponding with the loudest response in the telephone, and the point is sharply defined, you know that you have your wave meter in resonance or in tune with the transmitter whose frequency or wave length is to be measured. You can then read the wave length directly off of the scale, if it be calibrated in frequencies or wave lengths; or if it be calibrated merely in degrees,

you can refer to a table belonging to the instrument, which will then immediately give you the wave length or frequency of the transmitter. Upon the table you will see four small glass tubes constituting spare platinum points of the primary cell detector.

This instrument may also be used as a standard for producing a wave of a definite frequency or wave length. To do this a small spark gap, whose terminals are mounted upon the box, is opened and the terminals connected to a very small induction coil. When sparks pass across the gap, the apparatus will produce waves of a frequency or length corresponding to the frequency or length of that point in the scale to which the pointer is directed. Thus, by moving the pointer to different positions you can produce any desired wave frequency or length within the range of the instrument.

The signal corps of the United States army has entered the wireless

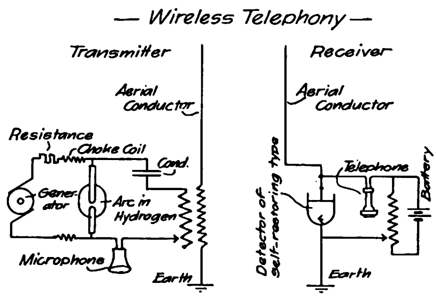


Fig. 19.

telegraph field and requires portable sets. The portable generator is driven by two opposed cranks, which are turned by several soldiers. This generator furnishes current for the induction coil or transformer of the transmitting outfit, which is located in a tent near by, the aërial conductor being held in the air by a portable jointed mast arrangement.

For wireless telephony any of the receiving arrangements and self-restoring detectors herein shown are suitable. The real problem in wireless telephony is in the transmitting apparatus, where it is necessary to secure either sustained oscillations, or wave trains or groups succeeding each other at a frequency above the limits of audition; and with either arrangement it is necessary to control the radiated energy by the human voice.

A wireless telephone system in which the oscillations are substan-

tially continuous or sustained is shown in Fig. 19. A generator supplies current through a non-inductive resistance and choke coils to the terminals of an arc which may be placed in an atmosphere of hydrogen. In shunt to the arc is a circuit including a condenser, a telephone microphone, and inductance, the latter being variable and serving as a primary of an oscillation transformer whose secondary is connected between the aërial conductor and earth. The capacity and inductance of the circuit including the arc and microphone is made such that high-frequency oscillations result in the condenser circuit. These oscillations seem not to die out or dampen at all; one oscillation succeeds the other with substantially uniform amplitude, so that there is radiated from the aërial conductor into space a continuous stream of waves, not broken up into groups, as in the case of Fig. 4, for telegraphy. By talking to the microphone, the amplitude of the radiated waves may be varied, perhaps somewhat in frequency, but principally in amplitude. At the receiver these oscillations become high-frequency alternating currents of minute power in the aërial conductor and pass down to a detector of the self-restoring type. The detector, as the Pupin, Vreeland, or Fessenden detectors, or silicon detector, or any other suitable self-restoring detector, causes the response in the detector to vary in accordance with the rising and falling in the quantity of the received energy, with the result that the current through the telephone varies in like manner and, consequently, reproduces speech.

But even though the oscillations produced by the transmitting apparatus are not strictly continuous or sustained, nevertheless they die out at a rate which is extremely small compared with the rate illustrated in Fig. 2. It may be that such a transmitter delivers overlapping trains of very slightly damped oscillations. In any event, such a transmitter and receiver suffices for wireless telephony.

Or the transmitter may be such that the sparks occur extremely rapidly; indeed, at a frequency above the limit of audition in the receiving telephone at the distant station. Indeed, a spark gap at a frequency of from five to ten thousand will probably in most cases suffice. Then the amplitude of the radiated energy may be controlled by a microphone, and at the receiving station the operation above described takes place, with the reproduction of speech. Because the energy is transmitted in wave trains which succeed each other at a rate above audition, the detector at the receiving station responding at such high rate, there is no noise produced in the tele-

phone. Only speech is reproduced in the telephone, owing to the rise and fall of the energy at a much slower rate, corresponding with the far lower frequencies characteristic of the human voice. Such a spark gap system is shown in Fig. 20, where the generator, G, is of sufficiently high frequency to produce wave trains or groups which shall be above the limit of audition in the receiving telephone. Here the microphone, K, is placed directly in the aërial near its base, and being in this position varies the amplitude of the radiated energy in accordance with speech.

Another method of wireless telephony is one in which the amplitude of the radiated energy is not varied in accordance with speech.

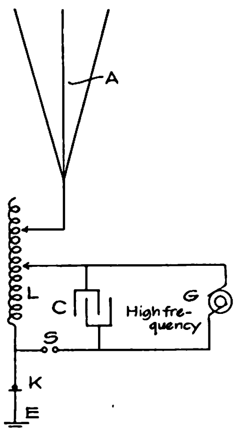


Fig. 20.

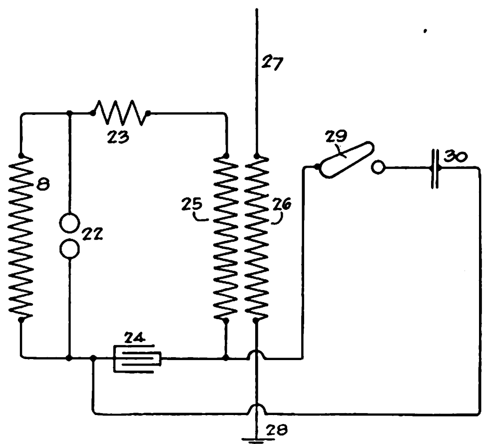


Fig. 21.

On the contrary, the amplitude of the radiated energy remains substantially constant, but the *frequency* of the energy is varied in accordance with speech.

A transmitter for such purpose is shown in Fig. 21, where 8 is the secondary of a transformer delivering current at a frequency above the limit of audition to the circuit including the spark gap, 22, inductance, 23, the condenser, 24, and the primary, 25, of an oscillation transformer whose secondary, 26, is connected between the radiating conductor, 27, and earth, 28. The telephone transmitter in this case is the condenser, 30, which is connected when the switch, 29, is closed in parallel with the main condenser, 24. By talking against one of the armatures of the condenser, 30, the distance between the

armatures is varied, and, therefore, the dielectric between the armatures is varied, with a resultant variation of the capacity of the condenser, 30, in accordance with speech. This then varies the natural period of the circuit of the main condenser, 24, in accordance with speech, so that the radiated energy, while remaining substantially constant in amplitude, varies in frequency in accordance with the human voice. At the receiving station the self-restoring wave detector, such as the Pupin or silicon detectors, may be connected in any suitable way, such as in shunt to an inductance, and such that it shall be responsive to frequency changes and thus cause in the telephone the reproduction of speech.

In Fig. 22 the same frequency variation is shown in a transmitter involving an arc producing sustained oscillations instead of separated

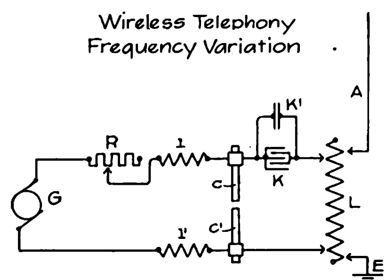


FIG. 22.

wave groups, as in the preceding figure. Here again speech uttered against the condenser, K, will vary the frequency of the transmitted energy by and in accordance with speech.

From Europe come reports that wireless telephony has been successful over distances of from 100 to 250 miles; and in this country, the author believes, several have been able to communicate over 100 miles. The arc system is generally used for such purpose, but there are inherent disadvantages in the arc system in getting sufficient energy into space. The arc system is quite suitable where relatively small amounts of energy are transmitted.

And from the fact that an ordinary microphone can safely handle only relatively small currents, the improvements are in the direction of controlling greater and greater amounts of radiated energy by the voice.

DISCUSSION.

H. C. Snook.—I have here a communication from a friend of mine, a Mr. Isbell, who has recently established connection for the first time between the Hawaiian Islands and the western coast of the United States by means of wireless telegraphy. This letter is under date of November 2d. After thanking me for calling his attention to one of the new detectors, namely, the "Tantalum detector," he says:

"I can hear Sitka, Alaska, 2400 miles, and every station on the coast down to San Diego, Cal. Have exchanged long messages, some of them Associated Press messages, and private messages with 'PH,' which is the signal of the station of the United Wireless Company's station at San Francisco, and I worked to the coast on 4 K. W. apparent energy."

Again he writes: "One night I worked with a steamer in Behring Sea, the fleet 1000 miles in the South Seas, the cruiser 'Colorado,' 1100 miles to the east, and 'Frisco, 2100 miles to the east, all within two hours—quite an area."

I would like to say, in the matter of general discussion, that it is a great pleasure to me to find so coherent a résumé of the development of the art at this time. I recall how the first few years of the development of wireless work were extremely disappointing, and very disgusting, if you please, because of the extreme lack of quantitative measurement of the things with which the experimenters were dealing. Quantitative results were the most unusual things to be found in the reports of wireless work. The English, who at first were the most active experimenters, delivered themselves in generalities, failing to give definite results, and other workers did the same. Mr. Ehret has shown us to-night lantern slides of apparatus giving definite measurements of wave length and frequency, and the results which he has recorded have been quantitative. This is entirely different from the early stage of the art, and is one of the most gratifying things in connection with "wireless" at the present time.

Mr. Marburg.—Does the same receiver answer for both telegraphic and telephonic work?

Mr. Ehret.—The same receiving apparatus may be used for wireless telephony as for wireless telegraphy, provided the detector used for telephony be of the self-restoring type and sufficiently quantitatively responsive. The simultaneous transmission of a wireless telegraphic and wireless telephonic message would not necessarily interfere at the receiving station. By suitable tuning apparatus, involving a refined adjustment of capacity and inductance, the receiving apparatus may be made substantially selective of either one message or another.

Mr. Carl Hering.—Then do I understand that it is possible to send two messages in different directions at one time? That is, a message can be sent east and at the same time another sent west across the Atlantic? I know that theoretically it is possible, but is it actually being done?

Mr. Ehret.—Yes; while high-power stations are working with each other over considerable distances, battle-ships with other ships equipped with wireless between them and the transmitting station, can be engaged in communication with each other without any interference from any of the other stations.

I believe that in the case Mr. Snook spoke of, involving 2400 sea miles from Sitka, Alaska, to Honolulu, the transmission spoken of occurred at night. Elec-

tric waves are much more easily transmitted at night than in daytime; that is, with a transmitter of a given power, messages can be received from that transmitter at greater distance at night than by day. It is attempted to explain this phenomenon from the fact that when the sun is shining the air between transmitting and receiving stations is affected by the ultra-violet light, which tends to make the air slightly conducting and thus absorb some of the transmitted energy. Of course, at night the ultra-violet light is substantially absent, and the air is supposed to be less conductive, with resultant better transmission.

I would say that the 1 per cent. variation in frequency was the limit on contracts by the Navy Department in tuning in wireless telegraph work. In wireless telephony by frequency variation it would be better to have the range wider.

Interference in such a case is within the bounds of possibility. If a telegraph transmitter is sending with a frequency which comes within the range of frequency variation in the telephone system, the telegraph signals may be superimposed upon the telephonic message.

Mr. Hering.—Has anything been accomplished in the direction of concentrating these waves so as to confine them to one general direction? I believe such attempts were made early in the history of wireless telegraphy, but I understand they never came to anything.

It has been claimed that the Atlantic cables would tend to lead the wave trains across the Atlantic in a general direction of east and west. A wave tends to follow the direction of a metallic conductor. Has such an effect been noticed in the transmission across the Atlantic?

Mr. Ehret.—I think your conclusion in general is correct. It has been attempted to concentrate the energy in its transmission to a given direction. From the base of the sending antenna a conductor has been extended out toward the receiving station in an attempt to confine the radiations within a certain plane. I believe that a measurable concentration within an angle of about thirty degrees has been attained, but so far as I know it is far from practical.

The case assumed by you in connection with cables is extremely improbable, because the cables lie at such considerable distances from the transmitting aërial conductors. I doubt whether the Atlantic cables assist in any way in the transmission of electric waves in the direction in which the cables extend.

Mr. Snook.—Directly bearing on this point, I am quite sure it is the experience of operators that they have not noticed any difference whatever in the character or the quality of the "ground" that they have obtained, when a submarine cable is near or far removed from the base of the aërial wire. Whenever they are able to obtain a good ground, the conductivity of the salt water is entirely sufficient to override the slight additional conductivity which would be given by the presence of the submarine cable.

Another point I failed to mention when reading Mr. Isbell's letter is in connection with the relative sensitiveness of this zinc oxide detector as compared with the sensibility of other detectors which are popular. Mr. Isbell says that when receiving messages coming from the western American coast he is able to receive messages clearly with the zinc oxide detector, but is unable to receive any signal whatever with the electrolytic receiver, which, at the time the zinc oxide detector appeared, was perhaps the most sensitive that had been discovered. He is able to make the coast hear him quite as clearly as points on his own side of the water.

Paper No. 1080.

UNDERGROUND CONDUIT.

PAUL W. ENGLAND.
(Active Member.)

Read December 19, 1908. *Revised October* 1, 1909.

Thirty years ago, when the electrical industries were in their infancy, underground conduit, as we are familiar with it to-day, was practically unknown, and such wires as were necessary were run overhead on pole lines or house-tops. With the rapid growth of the telephone and the electric light, in the years immediately following 1880, the number of overhead wires in our cities increased to such an extent that it soon became evident they must be placed underground, and underground conduit and cable came into use; at first as an experiment, then as a practicable solution of the overhead wire problem. At the present time, in the congested centers of population, all or nearly all of the wires are buried out of sight, and the work of placing them beneath ground is constantly being extended to outlying districts, so that between Philadelphia and New York, for instance, we now find all of the long-distance telephone wires in underground conduit.

In this paper a brief description is given of the earlier forms of underground conduit laid in Philadelphia by the company with which the author is connected (the Bell Telephone Company of Pennsylvania) and the changes in construction methods from time to time. Present practice is treated somewhat in detail, giving reasons for each type or method; and, finally, some of the special cases of construction which have come under the author's observation are described, such as the crossing of bridges with terra-cotta duct instead of iron pipe, central office connections, canal crossings, the lowering of conduit, etc.

As can well be imagined, the earliest attempts at placing wires underground were crude and primitive. Tile duct was, of course, entirely unknown; likewise the so-called "pump log" or creosoted wood. Almost the earliest form of conduit of which there is any record was a simple wooden box placed in a trench in the ground. In

this box the cable or wires were laid from a reel driven alongside the trench. The box was then filled with hot pitch, the cover nailed on, and the trench filled. No mention is made of manholes, but from the description given it is probable there were none, the various lengths of cable being spliced directly together in the wooden box.

In Philadelphia the earliest type of conduit used was the so-called "pump log" or creosoted wood duct, of 2½-inch bore. It was laid about the year 1886 on Market Street between the Delaware and the Schuylkill Rivers, and during the next few years on the north and south streets from South to Vine.

Following the use of this style of conduit, cement-lined pipe was laid quite extensively for several years, and was at first thought to be a great improvement over creosoted wood, and to be practically indestructible. Cement-lined duct consists of a thin wrought-iron shell, lined with Rosendale cement, and comes in 8-foot lengths with a 3-inch bore. It is provided with cast-iron ball-and-socket joints at the ends, to insure proper alignment and provide flexibility in making turns, and is laid with a concrete envelope in much the same manner as terra-cotta pipe. The troubles experienced with this conduit were many. The cement lining was found to drop off and obstruct the bore of the pipe, and the rough, gritty surface of the cement made it difficult to pull in cable. For these and other reasons its use was abandoned about the year 1896 in favor of the terra-cotta pipe, both single and multiple duct, so extensively employed at the present time.

The manufacture of terra-cotta duct may be said to date from about the year 1890, when several companies in the middle west started making it, notably in Ohio, where there are large deposits of the particular kind of clay best suited to its manufacture. In this form of duct has been found a nearly perfect conduit, one which meets all the requirements of practice, can be laid readily, is reasonable in first cost, and is practically indestructible.

The earliest form of tile duct was the single section; later came a multiple duct with three, four, six, and more holes. Both styles are good, but the multiple is somewhat less expensive than the single duct, hence it is now quite generally used in preference to the other form. The single duct was given its first trial by the telephone company at Wilmington in the year 1897, and proved so satisfactory that it at once became standard. No radical changes have been made in the style of pipe, in the method of laying, or in the general

features of construction since then. About three years ago multiple-duct terra-cotta was adopted for general use in place of single-duct, for the reasons given above.

Other forms of conduit which might be mentioned are the stone or concrete duct, and the so-called "bituminized fibre," made of laminations of paper soaked in a bituminous compound. The latter is an exceedingly light duct and easy to lay. Nothing definite is yet known, however, regarding its life, and the first cost of the duct is greater than that of terra-cotta. From the data at hand in regard to these various styles of duct, none of them can be said to fulfil the requirements of practice as satisfactorily as either terra-cotta or creosoted wood.

The several types of construction are as follows:

Creosoted Wood.

Creosoted wood is in general employed wherever it shows marked economy over other styles of duct. Although the first cost of the pipe itself is about 20 per cent. greater than terra-cotta, the cost of the complete conduit for sections up to six ducts is less, owing to the fact that neither concrete base nor envelope is required. Creosoted wood is, therefore, usually specified for main and lateral runs of from two to six ducts, and for connections to buildings and poles. The pipe comes in 7-foot lengths, having a square external section 4½ inches by 4½ inches, with a 3-inch bore, and is provided with a mortise and tenon joint to insure proper alignment of the ducts.

Treatment of Wood.—The wood is specially treated with dead oil of coal-tar to prevent decay. It is first placed in sealed tanks and the sap exhausted, after which the dead oil of coal-tar is pumped in under pressure, so as to fill all the pores and open spaces in the wood. Fifteen pounds per cubic foot of wood is the usual treatment. Short-leaf yellow pine, red gum, or Norway pine are commonly used, as they are porous woods of even, straight grain which can be easily bored and shaped. The dead oil of coal-tar must contain not less than 40 per cent. of napthalene, which is the principal preservative of the wood. It must contain no acetic acids nor acetates, as acetic acid attacks the lead sheath of the underground cable and forms in time white lead, the process going on indefinitely until the lead sheath is entirely destroyed; nor more than 8 per cent. of tar acids, as a larger proportion is liable to corrode the sheath.

Although the life of creosoted wood conduit is, as yet, somewhat

problematical, there seems good reason to believe that when properly treated and laid it will last an ordinary lifetime. Practical evidence of its durability has recently been furnished by the conduit removed from Market Street during the construction of the subway. After fifteen years of service the pipe was found to be in practically as good condition as when first laid, and is now being used again for new work.

Grading Trench.—The bottom of the trench is graded so as to have a gradual slope from an intermediate point toward either manhole, which is termed "crowning," or an uninterrupted grade from one manhole to the other, with a fall of not less than 4 inches per hundred feet and preferably as great as 5 or 6 inches.

Grades are obtained by means of stakes driven in the trench at

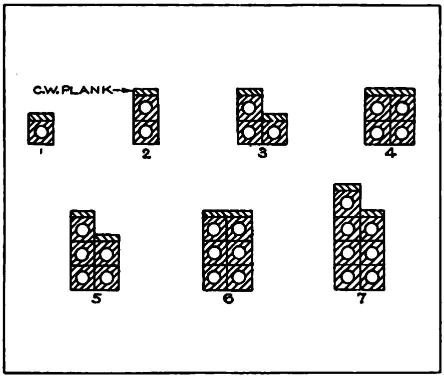


Fig. 1.—Standard cross-sections of creosoted wood duct.

intervals of 5 feet, three "tee" sticks being employed to set the stakes to the proper grade. The method of using the tees is to set one at either end of the trench and sight in the third at the various points between. Surveying instruments, such as level or transit, are rarely required in determining grades, though their use is sometimes indicated.

Method of Laying.—Standard cross-sections are shown in Fig. 1. The ducts are laid so as to break joints, both horizontally and vertically, and thus give strength to the structure. In joining the ducts the tenons and mortises are driven completely home, to form a tight joint. Except where laid on private property, a top protection of creosoted plank is used, 1½ inches thick and as wide as the duct

structure. Some companies make a practice of laying the ducts on a creosoted plank foundation, but this would appear unnecessary except where the soil is unstable.

The section of conduit is made as narrow as possible in order to effect a saving in top plank as well as in width of trench, repaving, etc. (See Fig. 1.) The average filling or cover over the conduit varies from 2 feet for the smaller sections to 2 feet 6 inches for the larger ones, and the average width of trenches from 15 inches to 18 inches, depending upon the number of ducts laid.

Terra-cotta Construction.

This form of duct, either single or multiple, is used for sections greater than six ducts and for all main runs that will contain trunk

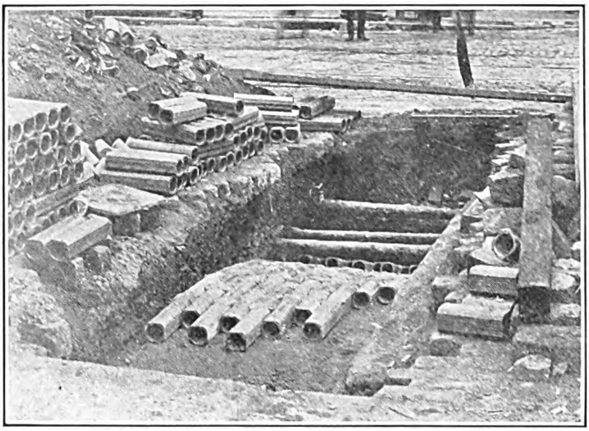


Fig. 2.—Twenty duct run at Fourth and Market Streets, showing flexibility of terra-cotta single duct.

cables. The best pipe comes from Ohio, and is made of the so-called "bottle" clay, originally used for making ink bottles, because of its non-absorbent properties. The clay is finely ground, and then burned until vitrified, all surfaces of the duct, both inside and outside, being glazed with a salt glaze. When laid with a concrete envelope, it is practically indestructible.

Single Duct.—For city construction, where foreign pipes, sewers, and conduit systems are frequently encountered, the single duct is often used in preference to other styles because of its greater flexibility and the increased ease of laying (Fig. 2). For making sharp bends

and turns short sections are used, varying in length from 3 inches to 12 inches. The standard length of the pipe is 18 inches, and the inside diameter either 3 inches or 4 inches, as required (Fig. 3). For the larger sizes of cables 4-inch pipe is now chiefly employed.

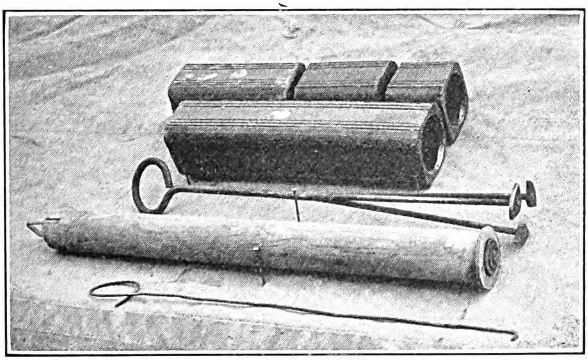
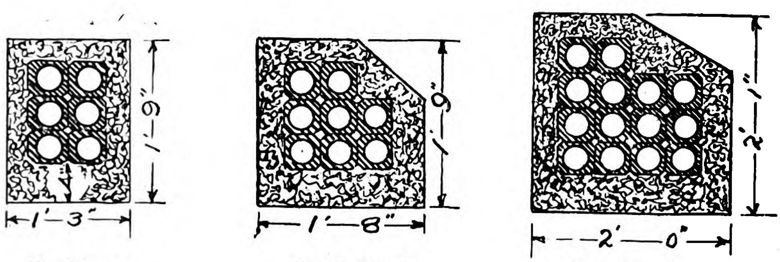


FIG. 3.

Before being laid all pipe is inspected and the inside thoroughly scraped and cleaned by means of a three-pronged steel scraper. The good pipe is then marked to indicate inspection and the bad pipe is broken and removed from the work.



Six Ducts. Eight Ducts. Fourteen Ducts.

FIG. 4.—Standard cross-sections of 3-inch terra-cotta single duct.

Standard cross-sections are shown in Fig. 4. The ducts are laid on a concrete base, either 4 or 6 inches thick, depending on the number of ducts, the concrete being allowed to set for at least one hour. Where added strength is required, the foundation is reinforced with rods or expanded metal. The pipes are laid in place in cement mortar

in much the same manner as brick-work, except that no cement is used in the vertical joints. They are laid so as to break joints, both vertically and horizontally, and true to a line stretched in the trench. In order to secure proper alignment a mandrel is always used in laying these ducts. It is made of wood, about 30 inches long, and is provided at one end with a heavy rubber or leather washer which tightly fits the bore so as to remove all projections of mortar that may be in the ducts (Fig. 3). After being laid the conduit is surrounded with a 3-inch envelope of concrete.

The concrete used for the base and envelope is composed of one part natural cement, two parts sand, five parts ¾-inch stone, and the cement mortar for laying the pipe of one part cement and two parts sand.

Multiple Duct.—Standard cross-sections are shown in Fig. 5, with

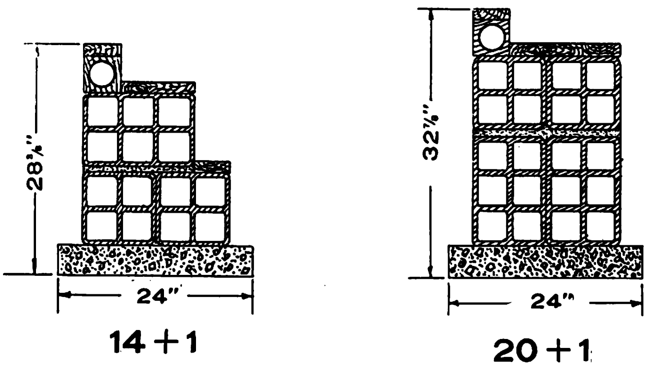


Fig. 5.—Standard cross-sections of terra-cotta multiple duct.

one creosoted wood duct on top of the conduit for distribution purposes. The most common forms of the multiple duct are the four-way and six-way sections, with a 3½-inch square hole, the length of the pipe being 3 feet. A concrete base 4 inches thick is employed, extending 3 inches beyond the conduit on either side. In laying, the pieces are carefully butted and centered, each section of duct being aligned by means of dowel pins. A creösoted plank placed on top of the duct furnishes protection from mechanical injury. The sides of the conduit are not, as a rule, protected with either concrete or plank.

Joints.—The matter of joint protection for multiple duct is, in the opinion of the author, of primary importance, because upon the quality of the joint depends, to a large extent, the life and efficiency of the

by several companies in Philadelphia, but the results obtained have not been entirely satisfactory, as the joint made with it does not prevent the infiltration of mud and water into the duct. In a short time after being placed the metal rusts away and allows the cement to drop off, thus leaving the joint with virtually no protection.

In order to remedy the foregoing defects a new form of joint protection has recently been devised by the author, known as the "concrete joint." In making the joint a sheet-iron form, 6 inches wide, 2 inches deep, and 2 inches longer than the height of the duct section (Fig. 8), is placed against the side of the duct so as to include the joint, and held in position by earth tamped back of it (Fig. 9). The form is then filled with thin concrete, composed of one part Port-

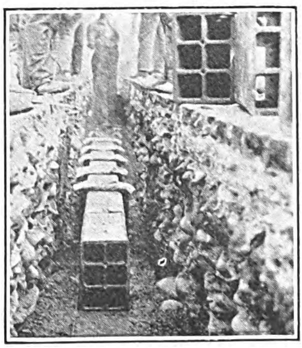


Fig. 9.—Joint forms in position at side of terra-cotta multiple duct, with cement bags on top, to prevent entrance of earth while filling back of forms.

land cement, two parts sand, and two parts grit or fine stone. A wrapper of paper, cloth, or perforated metal, applied when the duct is laid, seals the joint against the entrance of the mixture. As soon as the concrete is placed the form is withdrawn. The top joint is made by spreading on a layer of the mixture about 6 inches wide and 3/8 inch thick.

The process described insures a solid concrete band around three sides of the duct. Tests made by laying an experimental section of conduit and puddling the trench show that the joint completely excludes mud from the ducts. Although its first cost is about twice as great as that of the other forms described, its use is fully warranted by the added durability and efficiency given the conduit.

WROUGHT-IRON PIPE.

Wrought-iron pipe is used where the cover over the conduit must, for any reason, be less than 12 inches; in congested street-crossings where many pipes and obstructions are encountered; and for crossing bridges and water-ways.

Before being laid the pipe is given one coating, on the inside and outside, of coal-tar pitch varnish which has been heated to a temperature of between 300° and 350° F., the pipe first having been heated to the same temperature. Care should be taken to obtain a coating

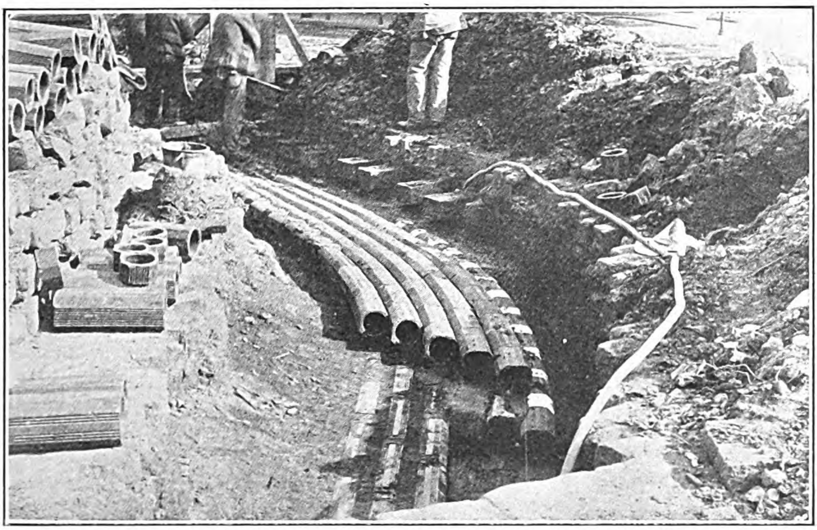


FIG. 10.

on the inside not affected by high temperatures, otherwise exposed pipe, as on bridges, is liable to give trouble in hot weather from the asphaltum melting and forming a viscous substance on the inside of the pipe, which retards the pulling in of cable.

Pipe after being laid in the ground is surrounded with a thin grout of concrete or cement mortar, which should entirely coat the outside of the pipe so as to leave no voids, as any exposed surfaces will rust and eventually pit through the pipe.

For joining separate lengths of pipe a so-called "slip" coupling has recently been used with good results. It is made by

reaming out the threads of the ordinary screw coupling so as to permit of slipping it over the ends of the pipe. By its use a marked reduction is shown in labor cost of laying the pipe. In a run of fourteen iron pipes recently laid over the top of the Rapid Transit Subway at Eleventh and Market Streets the estimated saving in labor amounted to about 35 per cent.

Connections with Other Ducts.—Iron pipe can be joined directly to terra-cotta pipe, either single or multiple duct, or to creosoted wood, as required. Insamuch as iron is much more expensive than the other styles of duct, it is customary to use as little as possible, piecing

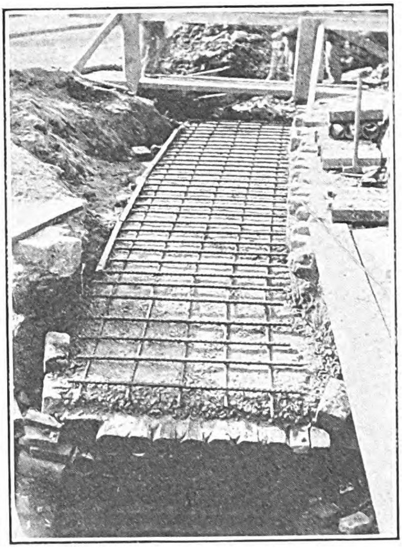


FIG. 11.—Reinforced covering for conduit.

on terra-cotta or creosoted wood at one or both ends of the run of iron pipe, as the case may be.

Connections between single-duct terra-cotta and iron are made by placing a standard socket on the iron pipe and butting short sections of terra-cotta duct directly to the socket, surrounding the joint thus made with Portland grout. Junctions with multiple-duct terra-cotta are made by means of special coupling castings. Connections with creosoted wood are effected by fitting the iron pipe into the mortised end of the wood duct.

Fig. 10 shows a run of fifteen ducts on Kensington Avenue between

two manholes about 75 feet apart, where iron pipe and terra-cotta single-duct are joined, as just described. The conduit crosses a

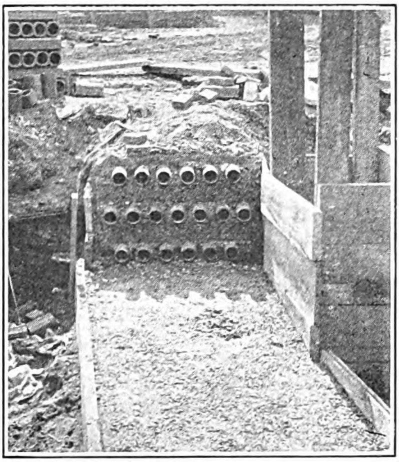


Fig. 12.—Subway crossing at Twenty-third and Market Streets; twenty-six wrought-iron pipes (one tier buried).

large filtration main at this point, and lies so close to the surface of the street that iron pipe was necessary at the crown. For each duct in the section one 20-foot length of iron pipe was used, and the

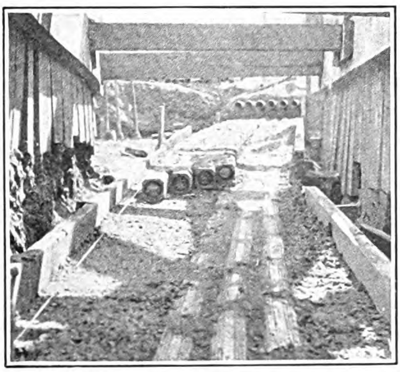


Fig. 13.—Method of changing section.

run then continued with terra-cotta. On top of the conduit was placed a 6-inch concrete slab reinforced with ½-inch and ¾-inch

rods to withstand surface loads and prevent crushing of the ducts (Fig. 11).

A shallow run of conduit across the top of the subway at Twenty-third and Market Streets, consisting of twenty-six ducts, wrought-iron pipe, furnishes another example of the joining of iron to terra-cotta (Fig. 12). It also illustrates the method of changing section between manholes, from four horizontal tiers, six and seven ducts wide, to the standard section, four ducts wide (Fig. 13).

Subsidiary Ducts.

Connections to buildings or poles consist, as a rule, of one duct of creosoted wood. They are generally laid at a less depth than the main run, the average cover being from 18 inches to 24 inches. Drainage is always toward the manhole, where possible, not toward the building or pole, so as to prevent water from entering the building or collecting at the base of the pole. When it is not possible to have the pipe slope continuously toward the manhole, provision for drainage is made by perforating the duct at its lowest point. Connections terminating in buildings are carefully sealed at both ends, as soon as laid, to exclude gas or water.

For connections to distributing boxes on buildings or poles a 2-inch wrought-iron sweep bend, of 2-foot radius, is used, equipped with special coupling to fit the mortised end of the creosoted wood duct. The vertical leg of the bend extends about 5 feet above ground and is fastened to the building or pole by pipe straps.

Cement sidewalks are tunneled in whole or part wherever practicable, to save the expense of repaving. When trenches are dug across lawns or parking, canvas, burlap, or tarpaulins are laid down before the excavation is started, and the excavated material placed thereon, to avoid unnecessary damage to the grass. Sod removed from trenches is carefully cut and cared for, and replaced upon completion of the work.

Manholes.

Manholes are located at street intersections, so far as practicable, care being taken to place them in line with existing conduit on the intersecting streets. The distance between manholes averages about 400 feet, and in no case should exceed 550 feet, as cable cannot be successfully pulled through longer sections of conduit.

Two styles of manhole are in common use, namely, the rectangular

and the oval-shaped, depending upon the nature of the conduit, whether main or lateral, the number of ducts, etc.

Rectangular Type.—Fig. 14 shows a typical brick manhole in Philadelphia, where the size allowed by the city authorities is, as a rule, not greater than 4 feet wide by 4 feet 6 inches long. Walls are usually 9 inches thick, built of hard-burned brick of good quality. The "head-room" under the roof averages 4 feet 6 inches to 5 feet.

A brick floor, with sand joint, is used in the majority of manholes, to permit of free drainage through the floor into the soil. A concrete base is employed only in special cases, where the soil is wet or un-

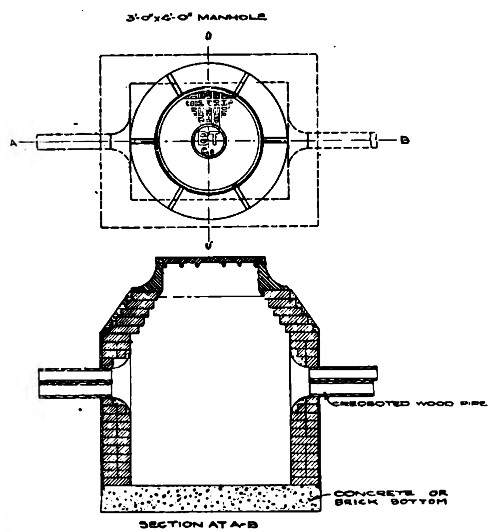


Fig. 14.—Typical Philadelphia manhole, size 3 feet by 4 feet.

stable. It is made 6 inches thick, and is covered with a 1-inch floor of Portland cement mortar.

Fig. 15 shows the special 2-foot 6-inch by 3-foot 6-inch brick manhole used at the end of lateral runs, and also over main runs where one or two ducts are cut, to provide for distribution purposes. It is 3 feet in depth and is provided with a rectangular manhole casting, in order to obtain the maximum working room when the cover is removed.

Oval Type.—In the oval type of manhole, used for heavy main runs outside of Philadelphia, greater length is obtained than is permissible

within the city limits. The length of a manhole is an important element in its design, and where practicable it should be at least 6 feet, to provide ample space for splicing and racking the larger sized cables, such as 440 pr. and 600 pr. The side walls of this type of manhole are made oval in shape to facilitate "forming" the cable around the manhole and to avoid sharp bends at the corners. The usual sizes are 4 feet by 6 feet and 4 feet 6 inches by 7 feet with headroom about 6 feet. The roof is built of I-beams and bricks, with round cover.

Manhole Castings.—A round iron frame and cover are employed on all manholes except those which, because of size and shape, require a large top opening when the cover is removed. Such manholes are the

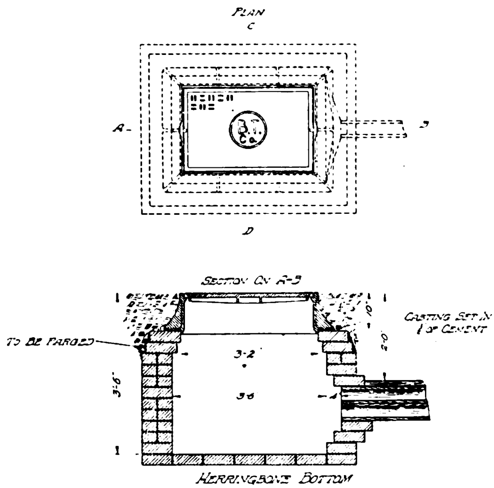


FIG. 15.—Distribution manhole, size 2 feet 6 inches by 3 feet 6 inches.

small 2-foot 6-inch by 3-foot 6-inch distribution hole and the 3-foot by 5-foot manhole used in suburban work. The frame has a depth of 10 inches and a maximum cover opening of 2 feet 5 inches. The weight of frame and cover is about 800 lbs. The casting is provided with a single cover in place of the two covers, inner and outer, formerly considered necessary to guard against accident from displacement. If the frame is well designed so as to furnish a good bearing surface for the cover, and a perfect fit, the liability of displacement of the top is practically eliminated. With but a single cover the locking feature of the manhole is, of course, lost; but this is no longer considered essential.

The rectangular casting is employed on distribution manholes (2 feet 6 inches by 3 feet 6 inches) and others which require a large top opening. The cover is 2 feet wide by 3 feet long, and the complete weight of frame and cover about 700 lbs. The objection frequently raised against a rectangular casting, that, if care is not used, the cover is liable to fall into the manhole and damage the cables, is not a serious one. In practice but little, if any, trouble is experienced from this cause.

Obstructions in Trench.

Service pipes running across the trench are among the most frequent obstacles met with in laying conduit, and should be avoided, if possible, by running underneath them. With heavy runs, however, it is often necessary to divide the structure so as to pass above and below the obstacle. In this event the pipe should be surrounded with sand or earth, and further protected on either side by wooden blocking placed so as to prevent the conduit from resting directly on the pipe.

When sewer manholes are encountered, the difficulty can usually be overcome by running the conduit through one wall of the manhole. In extreme cases, however, where the manhole lies directly in the line of the conduit, it must be completely torn out and rebuilt to one side so as to permit the structure to pass. Inlet necks running from catch basins to sewers are easily taken care of by relaying with special bends.

Special Construction.

Bridge Crossings.—For bridge work it was formerly considered necessary to employ wrought-iron pipe, but with the introduction of multiple duct there has come a radical change in methods of construction, resulting in a considerable saving in first cost, as well as a marked reduction in maintenance expense, which is one of the most important items to be considered in this class of construction.

The crossing of eighteen ducts on the Frankford Creek bridge (Kensington Avenue) furnishes a typical illustration of the newer methods. The bridge is of the plate girder type, with practically no space between the girders and the paving blocks. Consequently the only practicable method of crossing is by suspending the conduit from the under side of the girders. Seventeen U-shaped hangers are used, of 2-inch by ¾-inch wrought-iron, spaced on 11-foot centers,

and clamped to the flange of the girders as shown in Fig. 16. Each hanger is designed to carry a load of 3300 lbs. with a factor of safety of four. Resting on the hangers are two 5-inch I-beams, running the entire length of the bridge, and held securely in position at each hanger by U-bolts. Creosoted planking placed on the I-beams furnishes a suitable base for the conduit, which is laid directly on the planking without being bedded in concrete. Side and top protection is likewise of creosoted plank.

The saving in material from the use of terra-cotta multiple-duct in place of iron pipe, on this particular job, amounted to about $800,

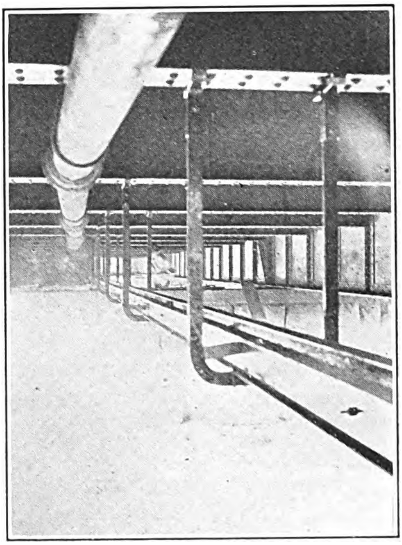


Fig. 16.

or 18 cents per duct foot, and the saving in labor was even greater. The cost of maintaining the crossing in good condition since its installation in 1905 has been negligible. The only cost in future should be for painting the hangers and I-beams.

Central Office Connections.—The run from an office manhole in the street to the basement of a central office building requires special study and design in each particular case. It is generally a heavy one, and may vary from thirty ducts to two hundred ducts or more. The style of duct most frequently used is wrought-iron pipe, because the street is usually more or less obstructed with water, gas, or sewer pipes.

At an office such as Filbert, where the main distributing frame is in the basement, the ducts are terminated flush with the wall and the cables are led out directly to the frame. At the Lombard central office, however, with the main frame on an upper floor, the ducts are brought all the way into the basement and stepped off in multiples of four and five, as shown in Fig. 17. The cable run is up the side of the wall and thence through a cable slot in the ceiling, suitable racks holding the cables in position. The walls, as well as the ducts in this room, are tiled, making it one of the handsomest terminal rooms in the country. Similar arrangement of ducts is found in all the newer

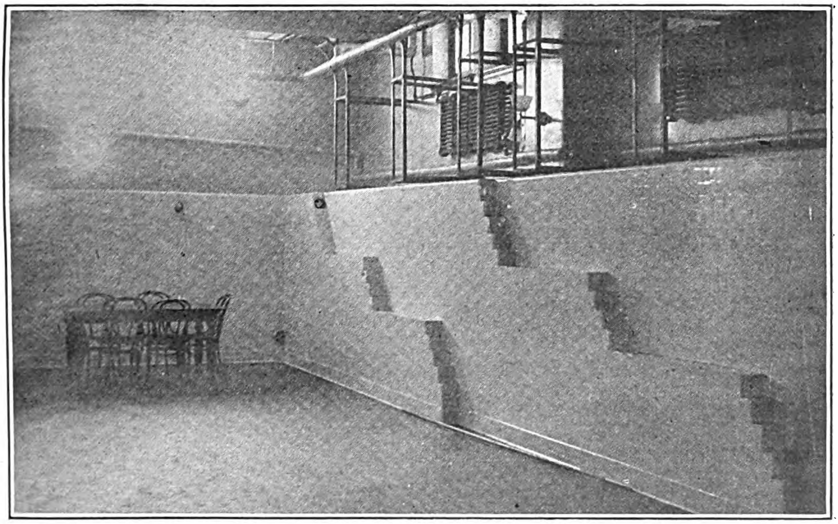
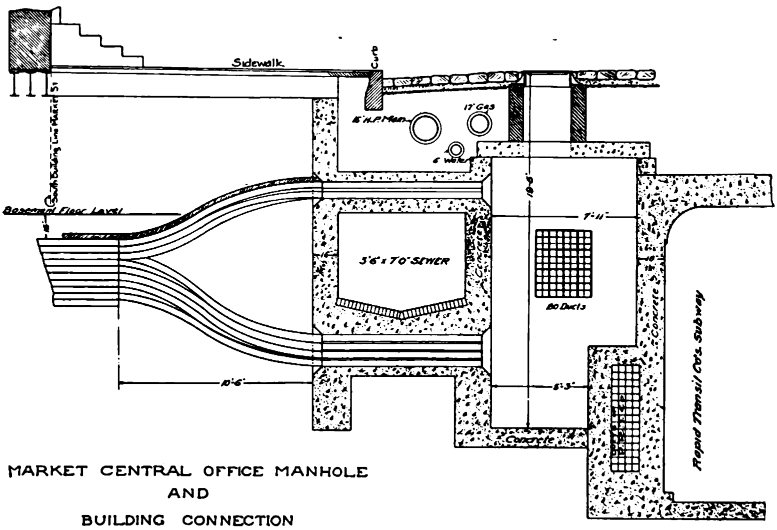


Fig. 17.—Lombard Central Office Terminal Room, showing ducts stepped off.

central offices in Philadelphia, such as Diamond, Dickinson, Belmont and Woodland.

The connection to the central office at 406 Market Street, relaid during the construction of the Rapid Transit Company's subway, affords an illustration of what can be done under adverse conditions without interruption to telephone service. The large manhole opposite the office, as well as a portion of the existing run of two hundred and twenty ducts to the basement of the building, containing about eighty cables, lay directly in the path of the subway and the new storm sewer on the south side of Market Street; consequently,

they had to be completely torn out and the cables raised up out of the way. Fig. 18 shows a sectional view of the manhole as reconstructed in the space between the south wall of the subway and the north wall of the sewer; also of the run of one hundred wrought-iron ducts passing under and over the sewer and thence to the basement of the building. Immediately after completion of the sewer, connection was made between the new ducts and a corresponding number of existing ducts at a point about 15 feet inside the building, and the cables were then transferred from the old to the new conduit.



MARKET CENTRAL OFFICE MANHOLE
AND
BUILDING CONNECTION
406 MARKET ST.

SECTION LOOKING WEST

FIG. 18.

Lowering Conduit.—Changes in street grade frequently require the lowering of existing conduit so as to conform to the new grade. If the conduit consists of creosoted wood, the operation is comparatively simple; but if it be of terra-cotta pipe, it presents greater difficulties. An operation of this sort carried on at Seventeenth and Indiana Avenue in 1904, illustrates the methods employed. The section of conduit lowered was 260 feet in length from manhole to manhole, being a portion of the main trunk line between the Poplar and Allegheny offices. It consisted of thirteen ducts terra-cotta pipe, surrounded with the usual envelope of concrete, and contained working cables. The change in grade was sufficient to expose the

ducts, if left in their original position, and, furthermore, was not uniform, being greater at one end of the section than at the other, thus necessitating differing degrees of depression at the various points of the conduit's length.

The most obvious method of lowering conduit, namely, by means of the ordinary jack-screw placed beneath the structure, seemed inadvisable here because of the difficulty of setting the jacks in position, the cramped space in which the men would have to work, and the impracticability of operating the jacks simultaneously so as not to put unequal strains upon the conduit structure.

In order to overcome these objections special jacks were designed, to be placed above instead of beneath the conduit. The screws were made 2 feet long, of 1¼-inch wrought-iron, seven threads per inch, and provided at the lower end with an eye-bolt to take the chain passing around and supporting the conduit (Fig. 19). On the screw turned a heavy nut, to which was forged a 2-foot lever arm, so that by turning the lever arm the screw could be elevated or depressed. This nut bore on a supporting wrought-iron plate with hole at the center large enough to clear the screw, and the supporting plate in turn rested on two 6-inch by 8-inch beams thrown across the trench at intervals of 10 feet 9 inches. The estimated weight of the conduit with its encasing concrete and nine cables was 560 lbs. per foot, making the load on each cross-support 6020 lbs., and the total weight of the entire structure, from manhole to manhole, about 72 tons.

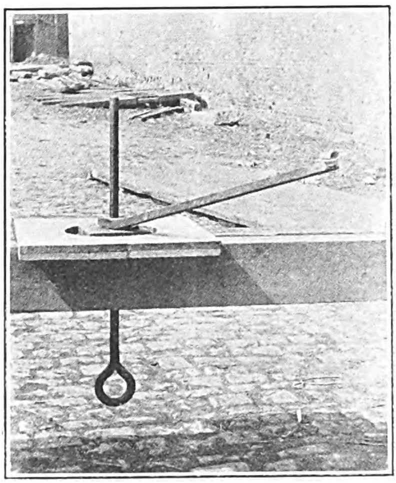


Fig. 19.—Special jack-screw designed for lowering conduit.

In lowering the conduit a workman was stationed at each of the twenty-four jack-screws. At a given signal from the foreman, each man gave the lever arm of his jack one complete revolution, and the operation was repeated until the conduit had been lowered 6 inches, corresponding to forty-two turns of the lever arms (Fig. 20).

For the differential lowering, that is, lowering one end of the structure more than the other, circular wooden templets were provided at each of the twenty-four stations, with divisions of 15 degrees marked on each templet. Starting at station No. 1, at the southern end of the line, each lever arm was given an angular rotation of 15 degrees more than its neighbor to the south; thus, while the arm at station No. 1 was being turned 15 degrees, the arm at station No. 2 received a 30-degree rotation, at station No. 3, 45 degrees, and so on, and at the last station one complete revolution. A pin with red tape attached, stuck into the templet, indicated the point to which the workman at any station should turn the lever arm each time,

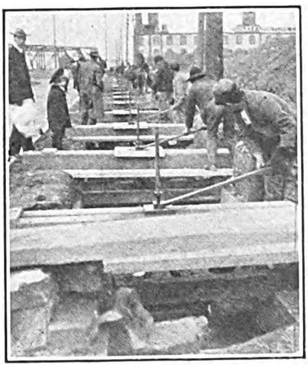


FIG. 20.—Method of lowering conduit.

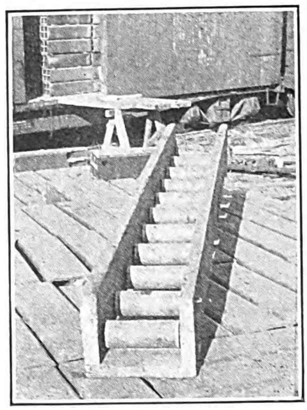


FIG. 21.—One section of roller chute for handling terra-cotta multiple duct.

the pins being readjusted after each rotation, and the operation repeated until the conduit had been lowered the required distance.

The total time required to lower the conduit 18 inches was about two hours, and the work was accomplished without cracking the concrete envelope. The cost of the operation amounted to approximately two-thirds of the estimated cost to lay new conduit, pull in new cable, splice it up, and pull out the old cable.

Cutting Asphalt.—Prevalent methods of cutting asphalt for trench work, by means of mattocks, possess many disadvantages, such as the danger of injury to pedestrians from flying chips of asphalt, damage to buildings, the necessity of placing burlap screens, etc. These disadvantages are obviated by the method, recently adopted, of using

wedges, which are driven into the asphalt along the side lines of the trench at intervals of from 3 inches to 6 inches, depending upon the hardness of the pavement. The asphalt is then readily pried up by means of the ordinary bars and picks. Comparative cost records of both methods show a saving of about 40 per cent. in favor of the newer one.

Handling Terra-cotta Multiple Duct.—The vacating of a storeyard containing approximately 500,000 duct feet of terra-cotta multiple-duct, or, say 35,000 pieces, required the loading of the pipe into cars for transportation to another section of the city. The pipe covered an area of about 50 feet by 100 feet and was piled 10 feet high. A

FIG. 22.—Old line of conduit on Market Street, raised above street level during construction of Rapid Transit Company's subway.

piece of four-way duct, 3 feet long, weighs 100 lbs., and can be handled by one man. The six-way duct, weighing 140 lbs. per piece, requires two men. The usual method of loading terra-cotta multiple-duct into cars is by means of hand labor, but in the present instance this was supplemented by mechanical methods. A trough or chute was constructed of 2-inch lumber, in 12-foot sections, provided with wooden rollers in the bottom 3 inches in diameter, spaced on 11-inch centers (Fig. 21). The chute is light, easily handled and flexible, and can readily be adapted to any of the varying conditions incident to loading cars. Pipe from any portion of the pile can be loaded into the car with almost equal facility, and the hand-carry is reduced to a minimum. By its use the labor cost of loading was reduced from

about $1.00 per thousand duct feet, the figure for hand-loading, to 80 cents, a saving of 20 per cent.

Market Street Conduit.—One of the heaviest runs of conduit in the city is the line on Market Street east of City Hall. This line, originally of 2½-inch creosoted wood and iron ducts, was entirely replaced, during the construction of the Rapid Transit Company's subway, with a new system of ducts, manholes, and cables.

A rather difficult feature of the work was the maintenance of the old system in good working condition while the subway was being constructed and the new ducts laid. The methods employed consisted in moving the old ducts to one side or raising them up out

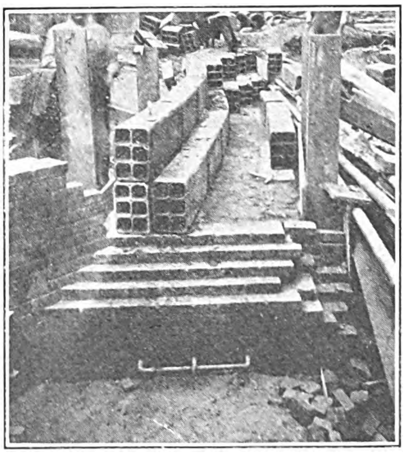


FIG. 23.—Sixty-duct run of terra-cotta multiple conduit entering manhole at Eighth and Market Streets.

of the way. In some instances it was necessary to elevate them above the street-level and suspend them from cross-supports, as shown in Fig. 22, thus providing clear space beneath for the subway work as well as the laying of the new line of conduit.

Terra-cotta multiple-duct is used throughout for the new run, the size of which varies from sixty to eighty ducts. The conduit rests directly on the roof of the subway for the main portion of the run between manholes, but where it enters the manholes, which are built off to one side of the subway to gain sufficient depth, it is curved over to enter them, as shown in Fig. 23.

The average size of manholes is 6 feet by 8 feet, with some con-

siderably larger; as, for example, the office manhole opposite 406 Market Street, which is 7 feet 11 inches wide by 22 feet long, by 19 feet 6 inches deep (Fig. 18).

The work required about two years to complete and was accomplished with practically no interruption to telephone service.

DISCUSSION.

Carl Hering.—How much protection, if any, do these conduits afford against electrolysis of the cable sheaths by stray currents?

Mr. England.—I might say that the terra-cotta and bituminized fibre ducts are of comparatively high insulation resistance as compared with the creosoted wood ducts. In actual practice, however, it has been found impracticable to depend upon the insulating property of the ducts to furnish protection against electrolysis, because the conduit cannot always be kept free from water or dampness. Even if the ducts could be made electrolysis-proof between manholes, there would still remain the difficulty of insulating the cables at the manholes. As a matter of fact, the danger from electrolysis is avoided by the use of a copper return bonded to the cable sheath at the manholes. In all cases where iron pipe, used as conduit, crosses bridges care is taken to insulate the pipe from the ironwork of the bridge so as to prevent the pipe and cables from picking up an excessive amount of current on the bridge.

W. C. L. Eglin.—It seems that the principal question raised is one of joints. There is a system of conduits that Mr. England has not touched upon, and that is the continuous concrete duct, which, I believe, was used in New York city some time ago. The principal feature of this duct was the use of paper envelopes of special oiled paper as a mold, the envelopes being inflated by means of an air-compressor. The paper envelopes were made in continuous sections and were laid between manholes in a conduit having a number of ducts. The paper envelopes were spaced by means of wooden racks. After the ducts were laid out for a section between manholes, all of the envelopes were inflated by means of an air-compressor and concrete was poured around them. As the envelope was flexible, it could be laid in any shape that the cable required, and could make small curves or bends around obstructions. It was claimed that the paper lining was an advantage in that it added to the water-tight feature of the conduit and made a smooth runway for the cable. It was also claimed that this type of conduit could be installed for less cost than either vitrified clay or iron pipe.

In regard to the water-tight feature: I agree with the opinion of others that it is impracticable to get a conduit that is perfectly water-tight and that arrangements should always be made for draining the ducts into the manholes.

Mr. England.—In regard to the continuous concrete duct mentioned by Mr. Eglin, I have had no experience whatever with this form of construction, although I have read descriptions of it. So far as I am able to judge, the method would be a wholly impracticable one to use, and it is doubtful if it would show a saving in cost. Whatever saving there might be in material, would probably be more than offset by the cost of inflating the tubes used for the interior forms. While the method might be considered interesting from an experimental stand-

point, I should say that it would fail wholly to meet the requirements of actual practice.

C. W. Pike.—I have had occasion to use almost every kind of duct mentioned by the speaker, and in turn gave up nearly all of them until the timely arrival of the terra-cotta duct. Among the ones mentioned by the speaker is the bitumenized fibre duct, which we have not used very largely, for the principal reason that it is not mechanically strong enough, under the influence of the sun's rays, to support its own weight without buckling. It does not seem that a conduit which must of necessity be piled out of the sunshine is one that we would choose in view of the rough conditions of underground construction.

In Mr. England's work he has in several cases come to the same conclusion that I have, and one is the desirability of a different joint from the one obtained with the grouting of muslin, and we have used somewhat the same arrangement as he shows us. We were also led to the desirability of using the concrete manholes, not perhaps in the same way that Mr. England was, but no less forcibly. On one of our jobs at one time the electrical workmen instituted a sympathetic strike that was ordered by one of the trades, and we had some of this underground conduit work to do. It was impossible for us to get bricklayers, so we had to use something that did not require a bricklayer. We had men who could have laid bricks well enough, but were not allowed to do it because on this property a house was being built by union labor, and we were not allowed to employ non-union men, so we used all concrete, and with great success. I was, of course, interested to know how the cost compared, and found as great or greater diminution in cost than Mr. England notices, because with the concrete construction we can use cheaper men than union bricklayers, so that unless our specifications state to the contrary, we have for three or four years been using concrete construction.

I notice in Mr. England's slide that he has obtained greater flexibility in the use of the rigid terra-cotta duct than I had supposed possible. I had always planned to make my runs absolutely straight, or close to it, but rigidity with him seems to have acquired the qualities of rubber hose. I would like to know what method he uses for fishing around these comparatively sharp curves shown on the screen.

Mr. England.—Regarding the method of wiring ducts around curves, in case the curve is too sharp to permit of using the regular jointed or screw rods of wood, which come in 3-foot sections, a special flexible, steel wiring-tape is employed, similar to the one used for threading interior conduits. It is advisable, of course, to make the conduit runs as straight as possible. Where curves cannot be avoided, however, the distance between manholes must be considerably shortened. Curves with a radius as short as 10 feet or 15 feet are not uncommon, and no difficulty is experienced in drawing cables around them.

Edward Cunningham.—Has Mr. England ever tried the asphalt and burlap joint? It was tried in New York on the Third Avenue construction with 72 or 76 ducts across Forty-second Street. I am in doubt how that work proved out.

Mr. England.—I believe the asphalt and burlap joint was the earliest form used with the multiple duct. It is not considered as effective as the cheese-cloth and cement joint, and the latter form is far from satisfactory. I have seen a good many of these joints dug up after having been in the ground a number of years, and in almost every instance the joint was completely gone. The same is true

of the perforated metal and cement joint, for the thin metal soon rusts out and the cement drops off. Even the concrete joint which I have described is not entirely free from this defect, although it is much more so than any of the other forms. The duct is scored near the end by small grooves running around the pipe, and this scoring insures adhesion between the concrete and the pipe.

Solomon Swaab.—In conjunction with the Subway we laid upwards of 250 miles of terra-cotta ducts on Market Street, and it often struck me that a butt joint in terra-cotta telephone duct was not the best sort of a joint, and I think a bell and spigot joint could be devised which would answer the purpose. I understand that what telephone engineers principally require is to keep out the earth and the cement used in laying the ducts, and in this I am sure that they are not always successful. I have seen some obstructions removed from terra-cotta ducts; for instance, in a Bell conduit which was illustrated by Mr. England as located at Third and Market Streets. When it came to pulling in the cables, it was discovered that one of the ducts was obstructed, and one of Mr. England's assistants had us open the street and break into the duct, and we discovered that ice had formed in one of them. The water had undoubtedly gotten through the joints and frozen there. It seems to me that as they do not require an absolutely tight joint, some kind of a slip joint might be devised that would do away with the muslin or metal joint material.

Mr. England.—As to the duct with bell and spigot joint, mentioned by Mr. Swaab, there is a single-duct terra-cotta pipe made with such a joint, but no multiple duct, so far as I know. It would be exceedingly difficult to manufacture the multiple duct with the bell and spigot joint. So far as the single duct is concerned, the butt joint is considered superior, in practice, to the other form of joint.

James Heywood.—In power cable work one of the most important features is to prevent bending at a sharp angle by the splicer. The objection raised by the city authorities to large manholes is chiefly on account of the width, which interferes with parallel structures. A manhole 3 feet 6 inches wide and 9 feet long works very well on account of its extremely narrow construction. It absolutely prevents that sharp kinking of cables which is so dangerous to power cables.

I was much interested in Mr. England's paper, and particularly in the fact that he still continues to use wooden ducts. We have had wood ducts in service since 1893, and some of those taken out recently were pretty well rotted out. Another disadvantage of the wood duct for power cables is its tendency to take fire in case of a burn-out. Last week there was a burn-out in one of the up-town districts and the ducts were all destroyed, cutting off all power from the entire Kensington district. The fire also retards the progress of the work of repairing the cables. The ducts have to be torn up and taken apart and the fire extinguished before anything else can be done.

Cement-lined ducts were touched upon. We have had a large number of these in service, but found one of the objections is the cast-iron collar which is used on the end of the duct to provide a bell and spigot joint. This collar projects through the cement and comes in contact with the lead sheath of the cable. In cases of burn-out where large quantities of current are carried off to return cables and other ground construction, we find that a patch is burned out on the lead at each of

these collars. That, of course, applies to grounded railway circuits more than to metallic power circuits.

In connection with fibre ducts, the trouble from melting or sagging in the sun has been experienced by others, but I believe there are fibre ducts made now which do not do this. In fact, we have some of them in service. One of the chief advantages of the fibre duct is the possibility of aligning it nicely. Some of the bends shown by Mr. England would not be practicable for heavy power cables on account of the cable's extreme stiffness, and for this class of work the alignment feature is perhaps a little more essential than when the ducts are intended for telephone cables. The fibre duct presents a smooth surface on the inside and cables are readily drawn through it.

In connection with the matter of joints, it has been our practice to use, wherever possible, a quick-setting cement on the joints. We have had some experience with Portland cement, and find that it gets through the joints and forms little mounds or spikes inside which are hard to remove.

The multiple duct has advantages in its cheapness, but for our work has some disadvantages. The walls are thin, and consequently the cables are close together where they go into the manhole. Cables usually burn out at a bend, and the most severe bend is usually at the mouth of the duct, where the adjacent cable is likely to be damaged. With a thicker wall the liability to burn an adjacent cable is not so great, and the single terra-cotta duct has that advantage. It is also better in the case of excavations under the conduit, as the concrete envelope forms a very substantial beam which will support the conduit without shoring across a ditch 6, 8 or even 10 feet wide.

As to whether a duct should be made square or round, I understand that some of the service companies favor the square duct on account of the corners being able to receive small particles of dirt or stone when a cable is drawn in, without interfering with the cable. On the other hand, the round duct can be readily cleaned by plungers and other cutting tools, whereas the square duct has not that advantage.

Paper No. 1081.

THE ORGANIZATION OF THE BUREAU OF SURVEYS.

E. J. DAUNER.

(Junior Member.)

Read before Junior Section, January 11, 1909.

The organization of the Bureau of Surveys dates from the second day of February, 1854; under what is known as the "Act of Consolidation," by which the various districts of Philadelphia were brought under the legislative control of the mayor and Councils, the city limits being extended to the county limits. The city was divided into twelve survey districts, one surveyor being elected to each district by Councils. Councils also elected a "chief engineer and surveyor," who, with the twelve surveyors, was to constitute a "Board of Surveyors."

The Chief Engineer, with the advice and consent of Councils, was to appoint the following officers: a recording clerk, who acted as secretary of the board and kept the minutes, and assisted generally in the office; a draughtsman; and a rodman, who acted as messenger.

All plans, records, etc., made by the district surveyors were to be the property of the city and to be turned over to their successors when their terms of office expired. The District Surveyors, in addition to their salaries, were allowed to make charges for work done for corporations or persons, according to a fixed scale uniform throughout the city.

On March 27, 1855, Councils in joint session elected Strickland Kneass to the office of Chief Engineer and Surveyor, together with twelve district "Surveyors and Regulators." These gentlemen met once and organized by electing Mr. Kneass president of the board. They performed no other duty, as they were superseded by a supplement to the Act of Consolidation dated April 21, 1855, directing that the members of the Board of Surveyors be elected by the votes of the twelve districts into which the city was divided; one to be elected in each, to serve for five years, "who shall have had five years' experience and skill in his profession." The supplement also directed

that the board should be organized by the election of the chief engineer as president.

The district surveyors were elected on May 1, 1855, and organized as a board by electing Strickland Kneass president.

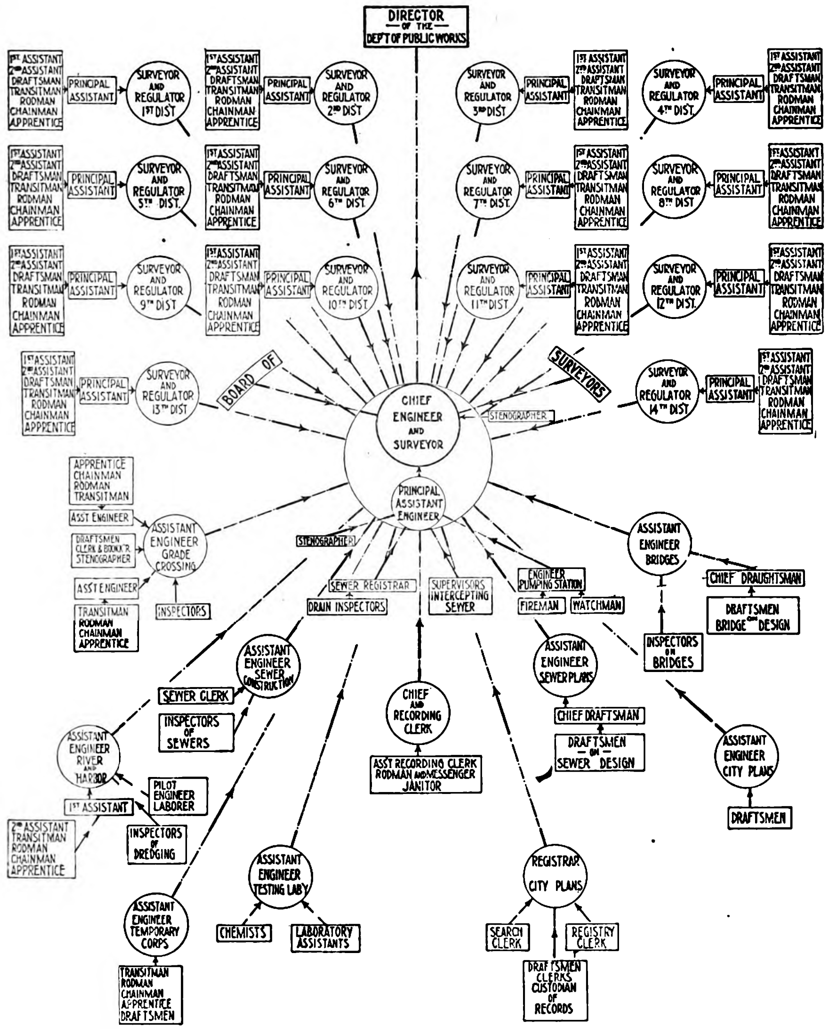
Strickland Kneass was an efficient head of the Survey Bureau and left a great many works to his credit. He was re-elected three times, each time for a term of five years. He organized the Bureau of Surveys and the Registry Bureau, and their development under his direction may be regarded as one of the most valuable results of the consolidation. Under his surveys the entire drainage system of the city was provided for, resulting in the construction of the great sewers to carry the waters of the Cohocksink Creek in the northwestern, and of Mill Creek in the western part of the city. Of the various bridges that span the Schuylkill River, those at Callowhill Street and at Chestnut Street are from his designs. He was one of the first to encourage the project of city passenger railways and was chief engineer of many of these companies. He resigned the office of chief engineer and surveyor March 6, 1872, to accept the position of assistant to the president of the Pennsylvania Railroad.

The new city charter, approved June 1, 1885 (the Bullitt Bill), which became operative the first Monday of April, 1887, repealed the acts of February 2, 1855, and April 2, 1855; and Councils were authorized by "ordinance to divide the city into such survey districts as to them may seem proper. Until the expiration of the respective terms of office of the present district surveyors such surveyors shall be attached to the Department of Public Works, and shall perform their duties under the direction of said Department."

This act also placed all employees under civil-service rules and regulations, and changed the method of compensation for district surveyors from the old fee system to a salary basis.

The ordinance of December 30, 1886, provided that the survey districts remain the same, and that, at the expiration of the terms of office of the then acting surveyors, district surveyors be appointed by the Director of the Department of Public Works, subject to the approval of Select Council, for a period of five years, with the same duties and responsibilities.

From time to time since that date the work of the Bureau of Surveys has been extended, until at present the organization and range of work covered is as shown on the diagram on page 55, a



DEPARTMENT OF PUBLIC WORKS
BUREAU OF SURVEYS
ORGANIZATION
1907

copy of one prepared for the yearly report of the Bureau of Surveys for 1906. It shows concisely and clearly the responsibility of each employee and engineer to his immediate superior, and the whole to the Director of the Department of Public Works. Taking the divisions in detail, the duties of each are as follows:

The Board of Surveyors is composed of the surveyors and regulators of the fourteen districts into which the city is divided. Twelve have been mentioned; the Act of Assembly of April 13, 1868, creating the Twenty-fourth Ward, made it also a survey district—the thirteenth. The fourteenth district was created by ordinance of December 30, 1901, dividing the tenth district in two.

The board sits regularly on the first and third Mondays of each month. Special meetings are held to visit localities affected by proposed changes in the city plan or to further important work. Road day meetings are held regularly every three months; special meetings when necessary, at which property owners affected by proposed changes in the city plan may appear and give testimony for or against the said changes. On this testimony and the judgment of the Board of Surveyors depends the confirmation or rejection of a city plan or changes therein.

The Board of Surveyors also passes judgment on the location of new tracks and curves, changes in location, style of rails, etc., of passenger railway companies; ordinances and petitions for constructing main and branch sewers, placing of new streets upon the city plan, striking off old ones and vacating streets and roads, and for revising and establishing lines and grades, etc., are received by the board, considered, and reports returned to Councils. The board approves deeds of dedication and releases of property owners for beds of streets about to be placed upon the city plan or releasing rights for damages sustained by reason of revision.

Individually each member of the board has charge of one of the districts. In each district the number of employees is varied to suit conditions; outlying districts where a large amount of suburban development is taking place have the greater number.

The work in the districts consists of the field work of the bureau generally, making of surveys and plans, and staking of lots and properties for individuals and corporations, and the preliminary survey and field work for the planning of sewers. In the case of main and intercepting sewers the details are worked out and plans made under the assistant engineer of sewer plans, the details and

plans of branch sewers in the districts, from standard specifications prepared by the Sewers Plans division, the final approval resting with the Board of Surveyors.

The construction of sewers, after the contract has been awarded, falls under the Sewer Construction division, an inspector from this being assigned to each sewer. In some cases where localities are not too widely separated an inspector will have charge of two or more sewers. His duties consist in seeing that the specifications and plans are followed by the contractor; in a diary he keeps a record of work done each day, amount of ground broken, trench opened to full depth, masonry constructed, number of slants and laterals built, amount of trench refilled, etc.

On completion of the sewer this book is turned over to the district surveyor for comparison and his signature. The sewer is then measured by the district surveyor and a plan prepared showing the requisite details, and bills are made out to the property owners along the street in which the sewer has been built. The plan and bills are signed by the district surveyor certifying to their correctness, and, with other papers, returned to the bureau. The bills are turned over to the contractor for collection, the city paying the difference between the total amount of the bills and the contract price. In the case of a private sewer, the entire cost is paid by the builder of the sewer, with a fee to the city for supervision of the construction and the district surveyor's charges.

Plans and bills for water pipe laid by the Bureau of Water are also prepared by the district surveyor.

Field work, estimates, and plans for grading and paving are prepared, and after contracts have been let the work is staked out, inspected, and when satisfactory certificates of completion given; in the case of paving, the property owner being charged his frontage and the city paying for the intersections of streets, frontage of non-assessable property, and public alleys.

The field work, calculations, and draughting for the preparation and revision of city plans are performed by the districts; the final approval and confirmation being given by the Board of Surveyors.

Jury plans showing properties affected and to what extent, in the opening of streets, in the revision of lines and grades, or the construction of a sewer, are prepared for the law department in the adjustment of damages.

These few items will serve to give some idea of the diversity and importance of the work of the district offices.

For work done for individuals or corporations a voucher is issued stating the character of the work and the charge therefor. This must be paid at the office of the Receiver of Taxes at the City Hall, where the voucher is receipted. Thus receipted, it must be returned to the district office from which it was issued before the work is completed or plans made.

Credits are allowed for work done for any of the city departments. These are added to the actual cash turned into the city treasury in computing the earnings of the districts.

Grade Crossings Division.—By ordinance approved February 2, 1897, and an amendment approved October 16, 1905, Councils authorized the revision of lines and grades of such streets as would be necessary in the elimination of grade crossings of the Philadelphia and Trenton Railroad from Norris Street to Butler Street, the work to be done by the Pennsylvania Railroad under the supervision of the Bureau of Surveys, and the city to pay a stated sum to the railroad upon completion of the work.

Under authority of an ordinance approved October 13, 1906, the city entered into contract with the Philadelphia and Reading Railroad to allow the railroad to relocate, change, and elevate certain portions of the tracks of the Philadelphia, Germantown and Norristown Railroad between Green Street and Wayne Junction, and of the Richmond Branch between Somerset Street and Richmond Street, so that all grade crossings might be abolished along these lines, the city to pay one-half of the cost.

The city's portion of the work, consisting of the preparation of plans and specifications for the construction and reconstruction of sewers, grading, etc., together with the examination of plans and specifications submitted by the railroad, and inspection of the work, falls under the jurisdiction of the grade crossings division.

The Philadelphia and Reading Railroad has since decided to make the elevated structure a four-track road throughout. As the contract with the city called for the elevation of the present road, a portion of which is two-track only, a nice problem of adjustment confronts the grade crossings division in the decision of just what proportion of the total cost the city pays half.

The Rivers and Harbor Division.—Since the creation of the Department of Wharves, Docks and Ferries the work of this division

has been somewhat curtailed. Previous to the creation of this department the entire river and harbor improvement, as far as it concerned city expenditure, together with the maintenance, were under the jurisdiction of the rivers and harbor division. It is a hard matter just at present to tell where the jurisdiction of the one ends and the other begins. The matter of dredging, for example, there being no money available at present for this purpose, has been left in abeyance for future decision.

Sewer Plans Division; Sewer Construction Division.—These two divisions naturally fall together under the subject of sewers. As stated under the heading of the "Board of Surveyors," these divisions have entire supervision of the laying out, planning, and construction of the sewer system, or rather systems, of Philadelphia.

In designing the sewers, use is made of data collected by the district surveyors, and daily records of stream gages and pluviometers located in different parts of the city. Sewers are designed to carry a run-off due to a maximum intensity of three inches of rainfall per hour. This has been found to be ample; as, though in some few extreme cases the rainfall has exceeded this, once or twice an intensity in excess of five inches, the duration has been short—a few minutes—and confined to a small area, so that the sewers were able to take care of the extra amount of water.

In connection with this work a long series of observations to establish the relations between precipitation and run-off have been carried on; and from these an attempt has been made to give values to coefficients that affect run-off which would be of general application, at least in this city. While the practical results have been satisfactory, a sufficient number of observations have not yet been made to warrant the final adoption of a formula.

In the early days of sewer construction it was deemed sufficient to construct a culvert over a stream or to inclose it in a conduit. As the city spread these conduits were extended until they terminated at the banks of bordering rivers. The effect of this was to render streams unsanitary short distances away from built-up sections. In order to preserve the purity of streams, or to restore them to a state of purity, especially where they were depended upon to furnish water for potable use, the method of using intercepting sewers was later adopted, known as the "intercepting system," in distinction from the water carriage or combined system.

This system, first applied to the Schuylkill River to conserve the

water-supply, has been extended to apply to a number of streams with their tributaries in different portions of the city, and is still in process of extension. These sewers serve to improve the sanitary condition of the immediate neighborhoods, and are a betterment to the city at large.

Looking toward this, on July 20, 1907, an ordinance was passed by Councils appropriating a sum of money "to make investigation, and report upon a comprehensive plan for the collection, purification and disposal of the sewage of the city, together with such alterations and extensions of the existing sewerage systems as may be necessary."

The experimental plant near the Spring Garden pumping station used by the Bureau of Filtration was transferred to the Bureau of Surveys in connection with this work. Alterations have been made, and by now the plant is in working order.

Sewer Registrar.—In this division are kept all the records of sewers that have been built in the city. The information on some of the old records is, of course, very meager, but those of a later date contain more complete information. Here the contracts, the inspector's diaries, and the plans of completed sewers made by the district surveyors are filed, each having the same number. A general record is kept in a card index; each card, filed alphabetically according to street names, contains the location, size, and depth of the sewer, the number of the inspector's diary, and the date of completion; in the case of a private sewer a card of a different color is used, containing also the cost per foot building front of property, with the name of the owner.

The contracts and the inspectors' diaries are filed according to the number referred to above; the plans according to a locality index. There are at present over seventy-five hundred plans and diaries in constant use.

At this office the plumber desiring to make connection to a sewer makes application; a voucher is issued to him, which, upon being paid to the Receiver of Taxes, is receipted. He then returns the receipted voucher to the sewer registrar, who issues a permit to open the street and connect with the sewer, and at the same time the location of the nearest lateral or slant is given to him. These connections must be passed by the inspectors of drain connections before the ditch is filled in.

The importance of this division in the prevention of useless breakages of paving and openings in the street can be readily appreciated.

The Supervisors of Intercepting Sewers, as their titles imply, have charge of the intercepting sewers. They inspect all connections made and keep an eye on the maintenance of the sewers.

The Temporary Corps.—This is a misnomer, as the temporary corps has been in existence for about twenty years. It is in reality a sort of utility corps, the men being used wherever needed in the different divisions.

The Testing Laboratory is little known except to those who have come into intimate contact with it in the course of business. Its work is constantly becoming more valuable, owing to the increasing amount and variety of materials used in modern construction, and the greater appreciation being given to the knowledge and importance of testing them.

In the basement of the City Hall is installed a complete cement and concrete testing laboratory. In operation here is one of the largest hydraulic compression machines in the world; its capacity is one million pounds. The concrete cubes tested are generally made on the site of the work from materials in the mixing box, so that the results of the tests not only indicate the general strength of concrete, but also give a value for the concrete in each particular structure. As, for example, in the construction of the Walnut Lane Bridge, when test cubes were made a record was kept as to what particular part of the structure the batch of concrete from which the specimen was taken went into.

In connection with this work is a freezing plant, and a furnace capable of developing a temperature of 3200° F.

The chemical laboratory is located on one of the upper floors of the City Hall.

A list of the tests made during the year 1907 will serve to show the scope and character of the work done in this department: Portland cement, natural cement, concrete, concrete materials, sand, stone, and slag, concrete building blocks, natural stone, artificial stone, paving brick, steel for concrete, boiler steel, theater curtain asbestos, tile, lubricating oils, illuminating oils, paint oils, paints, asphalt, and coal. A total of 2419 tests, in all, were made.

In addition, investigations of a research character are continually being made, to further the knowledge of the different materials, and

to increase the efficacy both of the methods of testing and of the actual work.

City Plans Division.—The work of the city plans division covers a wide range of usefulness. Preliminary studies of city improvements, the extension of city plans, and revision, over undeveloped portions of the city are prepared here.

There are a great many objectionable features to the old gridiron system of laying out streets. In numerous cases it necessitated extreme cuts and fills in opening streets, thereby entailing heavy expenditures on the city for damages to properties affected, and holding back for a period of years the development along the lines of these streets. The aim of this division, in co-operation with the district surveyors, is to so lay out new plans and revise old plans as to make them conform to the contour of the ground as far as practicable, and to lay out drainage streets of good width along natural depressions or water-courses, with sweeping curves where necessary. The advantages of this system of street lay-out are many; less damage results to adjoining properties, a comprehensive system of drainage is more easily and less expensively carried out; and streets of this character form more convenient and direct means of communication between centers of population.

Studies for parks and the development of surrounding streets, with the proper approaches, and work of this character, parkways and boulevards, are all prepared and considered as part of the work of this division.

The Registry Division.—In this division are registered and kept on file all confirmed city plans, deeds of dedication, openings of streets by affidavit, etc.; and on plans and in plan books covering the entire city are platted to scale and numbered all properties, with the registered owners and the dates of transfers.

The duty of registering these transfers devolves by law on "the purchaser, devisee by will, the person to whom an allotment in partition shall have been made, or their agent." If this is omitted, the Recorder of Deeds is required by law not to record the deed without charging a fee for each lot described. He then transmits to the registrar the proper description and date of transfer and the names of the grantor and grantee. In sales by the sheriff it is his duty to transmit the information.

Copies on regular forms of the descriptions of properties transferred are filed and bound in book form, the plan books and lot num-

bers furnishing an index. All departments of the city government have access to the records, and the public also, in some cases upon payment of a small fee.

At the close of 1907 there were over 990,000 descriptions on file, and by this time the number is probably over one million.

The Bridge Division.—Prior to 1887 bridges were built under the Bureau of Highways; subsequently the bridge division of the Bureau of Surveys designed and supervised the construction of all bridges built by the city. There is very little that can be said of the work of this division without going into tiresome detail. It will be sufficient to mention the concrete arch bridge over the Wissahickon Creek at Walnut Lane, the latest example of concrete bridge construction, containing the longest concrete span in the world.

The Pumping Station is one that is maintained in the low-lying ground in the southern section of the city to prevent the accumulation of water.

The Chief and Recording Clerk is sufficiently described by his title; he takes the minutes of the board meetings and performs with his subordinates the usual duties of a clerical force.

The above description of the organization of the Bureau of Surveys, although short and of necessity leaving out a great many details, will serve to give some idea of how the city of Philadelphia copes with the engineering problems that confront the executive department of a large city. The Bureau of Surveys is essentially a bureau of construction, as, in the main, after the completion of work, maintenance and repairs fall to some other bureau or department.

GOVERNMENT INVESTIGATIONS AND TEST OF FUELS.

ADDRESS BY HERBERT M. WILSON.
(Of the Technologic Branch of the United States Geological Survey.)
(Visitor).

Read December 18, 1909.

THE technologic branch of the United States Geological Survey operates under three acts of Congress and follows three separate lines of investigation. One is the investigation and testing of the strength and durability of structural materials. (It is perhaps not generally understood, but these tests and investigations are by law strictly limited to materials belonging to the United States.) Another line of investigation covers the testing of coal and other fuels; and a third—the outgrowth of the numerous disasters and loss of life in mines—has to do with the investigation of mine accidents, to determine their causes and possible means of preventing them, and to secure greater safety in mining.

The fuel investigations arose from an appreciation of the fact that the fuel as used by the Government, and consequently by others, is not economically used, nor economically produced, and that there is considerable waste thereby. This has been accentuated in the last year or so from the investigations of the National Conservation Commission, which has thrown much light on the possible life of our fuel resources. The United States produced in 1908 over 415,000,000 tons of coal—a tonnage which exceeded considerably that of any other country in Europe, the next being Great Britain, with 292,000,000 tons of coal, with Germany a close third.

The production of coal exceeds very greatly that of the two precious metals, gold and silver; in fact, it is nearly double the combined production of all of the metals excepting iron. In 1880 the production of coal was only slightly in excess of that of gold and silver together, the latter production being nearly $71,000,000, that of coal $95,000,000; whereas in 1907 the production of coal was five times greater than that of the two precious metals. The increase in coal production in the United States, concerning which a great deal has been written in the papers since the report of the Conservation Commission, is, as you will observe, on a very rapidly increasing ratio. In

the period 1846 to 1855 only 8,000,000 tons of coal were produced in this country. The tonnage increased thence up to the period 1876 to 1885, when it was 84,000,000 tons. During the period 1896 to 1905 it increased to 283,000,000 tons, and in the last six years it increased to 436,000,000 tons.

Much that has been misleading has been written and said about the subject of the duration of the coal-supply. One theory is that the middle of the coming century will see the end of the coal-supply in the United States. Another is that it will last for about seven thousand years. Both guesses are about equally good, depending on the method of estimate. On the present increasing basis of production it would not take much over a century to utilize all the coal in sight in the United States. If, however, the annual production continue as now without increase, the coal-supply might last about seventy centuries. Many believe that the approaching scarcity and consequent increase in price of coal will teach us to use it more economically and to conserve the supply accordingly.

The "per capita" consumption of coal has been more than keeping pace with the increase in production. In other words, coal is being used in the industries at an increasing rate, which is represented by the use for 1880 of 1.4 tons per capita; 1892, 2.3 tons per capita; and 1907, 5.4 tons per capita per annum.

The Geological Survey is bending its energies toward finding out how the fuel-supply of the United States may be increased. This is being done by the geologic branch, mapping the coal deposits and furnishing samples on which the fuel division is making tests and analyses. This contemplates two lines of investigation:—one into the distribution of the coal in the country and sources of waste in mining and marketing it; the other having to do with the utilization of the coal, and the ways and means whereby the various coals may each be put to that use which will be most efficient, and thus conserve the supply.

The coal fields—to pass over them quickly—are well known to all of you. In this part of the country our tendency is to think of the eastern coal fields as the great source of supply of the country, yet on the map it is an insignificant area. The bituminous coal fields of the east, the bulk of which you think to be in Pennsylvania, are most extensive in West Virginia, Ohio, and Kentucky, thence to Tennessee and Alabama. There is a large coal field in Arkansas. In Texas, the Dakotas, and California there are large areas of lignite. In Oklahoma

there is also a good bituminous coal, running through Kansas, into Iowa, and thence into Indiana and Illinois. There is a small field in Michigan, and the Geological Survey is developing the outlines of very good bituminous fields in Colorado, New Mexico, Texas, and also in Utah, and some good bituminous coals again in Washington and Oregon. These coals to the number of over 200 have been sampled in carload lots by skilled mining engineers working for the Government. Sealed samples have been sent to the Government testing laboratories for test. Ultimate analyses have been made of several hundred of these coals from all over the United States, so that it is now possible to tell simply by the analysis in the laboratory where the particular coal comes from. The proximate analysis, which shows the amount of fixed carbon, volatile matter, moisture, and ash, is followed with calorimetric determination to show the number of B.T.U.'s in it, on the basis of which we are able to ascertain the fuel value of the coal, and to appraise it by conversion into money values.

The ultimate analysis is furnishing a most important and valuable instrument in the hands of the Government, by which to determine whether or not coal which is purchased on the old basis, as we call it,—namely, on the name of the selling agent or the mine, or the coal field from which it comes, such as Pocahontas, or Pittsburg or Clearfield coal, or what not—is what it is represented to be. The aim of the analysis in the past was to tell whether or not we were getting the quality of coal for which we were contracting, but by aid of the ultimate analysis we can tell now not only what region it comes from, and from what coal field, but also from what seam. That has come up in the matter of large purchases of late by the Government, wherein coals have been purchased on the trade name, and upon investigation it developed that the shaft went down from a tipple through which the coal was brought and loaded into the cars; that the original seam was worked out in that mine and the operators were delivering coal from another seam entirely, and one which went by another name.

It is well known perhaps to a great many of you that when coals are contracted for and sold under some trade name or other, any such method of sale gives very small opportunity for the purchaser to detect an unfair delivery in case the seller is short of the kind of coal for which he contracts. That is largely due to the fact that it was not realized until recently—at least the purchasers have not—that the mine name alone was not a sufficient key to the character

of the coal which was being bought. Mine shafts, as I have said, tap more than one body of coal, and there may be a vast difference in the quality of the coal coming from those bodies through the same tipple. The modern method of purchasing coal, that which is being adopted by many large buyers, and which is now almost exclusively employed by the Government, is the B.T.U. basis, or the ash basis in the case of anthracite, and all of that is done under the supervision and inspection of the Geological Survey.

About 700 samples a month are received in the Washington laboratory, coming from the Government buildings under the direction of the Treasury Department, samples covering nearly the whole country, from Los Angeles, California, to Eastport, Maine, and about forty separate Government buildings in the city of Washington, from a number of arsenals, various navy yards, and other sources of Government purchases. There was much opposition to this method of purchasing coal at first, but there seems to be much less of late, and there seems to be a better understanding as to the obligations of sellers and buyers; and it would seem that when the matter can be better understood, and the question of sampling can be better adjusted, and the calibration of the calorimeters can reach a point where those of private chemists, to which the coal companies send their check samples, will be in accord with the standard calorimeters of the Government, there will be less cause for friction than now.

In the first years of fuel-testing the Government inspectors sampled about 300 different kinds of coal in carload lots. Steaming, gas-producer, briquetting, coking, washing, and other tests were made on each coal with a view of determining the most efficient use of each. As a result it has been found that a coal from one field which can be used most economically for one purpose, say for producing steam, may not be economical for house-heating boilers or for gas-production.

Taking from these tests a few typical ones showing the character of the coal, it was found that West Virginia coal produces the greatest number of heat units, which run close up to 14,500 B.T.U.'s per pound, as received. Pennsylvania No. 4, a particular type of Pennsylvania bituminous coal, is next best, running about 14,000 B.T.U.'s per pound. From this, coals run down in B.T.U.'s through the various States to North Dakota lignite, which is lowest in B.T.U.'s. A somewhat fixed relation will be observed between the heat units in the coal and the amount of fixed carbon, the West Virginia coal having the

highest amount of fixed carbon. Pennsylvania, though next highest in B.T.U.'s, is a little below Arkansas in fixed carbon. While there is an irregular relation between the heat units and the volatile content of the coal, there is a well-established and very concordant relation between the moisture and the thermal units, and a somewhat similar relation between the amount of ash and the thermal units, so that these various relations are to a certain extent interchangeable, and the mere showing in the analysis of ash or moisture as being excessive, indicates reduction in thermal efficiency.

Only the other day an interesting question came up which brought out very clearly the value of this data, namely, as to what is the value of water-power as compared with coal as a power-producer. When one comes to answer that question for the whole United States, the question which will come first of all is the cost of installation of water-power in various parts of the country, and each case has to be taken by itself. Nevertheless, there are certain generalizations which can be drawn by taking water-power and reducing it to the basis of 24-horse-power service, and by taking the B.T.U. values of the coal in Arkansas, Washington, Illinois, or Pennsylvania, and finding out the number of B.T.U.'s required per horse-power hour. As these tests show, for instance, West Virginia coal would require about 2.8 pounds of coal per horse-power hour, North Dakota lignite about 6.5 pounds of coal per horse-power hour, and so on. Now, if a value is put on coal,—say Pennsylvania coal costs $3.00 within fifty miles of the mine, or West Virginia coal costs $1.15 within fifty miles of the mine, or North Dakota lignite $1.00 within fifty miles of the mine,—it may be found that the cheapest coal in dollars is the dearest coal to buy, because it takes about three times as much of the North Dakota lignite at $1.00 to produce a horse-power hour as it does of Pennsylvania coal at $3.00.

There are many ways in which this data may be made of commercial use by engineers; as it is published in the reports of the Geological Survey, it will furnish very considerable assistance in answering inquiries of the kind which have been just indicated.

The Geological Survey is now analyzing and testing coal representing purchases to the amount of 1,000,000 tons per annum, payment being made by the Government purchasing officers on the basis of the analyses as reported by the Survey. In Washington every time there is to be a delivery of coal at any Government building the telephone rings and an inspector goes down, and in the presence

of an agent of the dealer, samples the coal. A fairly good sized sample is taken,—probably sixty-five pounds in a ten-ton delivery,—a scoop-full at a time. That is taken to the laboratory and reduced in a crusher so as to get a fair can sample, and gradually worked down to a laboratory sample, which is then analyzed. Checked samples are kept in sealed cans in case of controversy, until final settlement is made.

Turning to another feature of the fuel work, that of the possibility of conserving the supply through a more efficient use of each kind of coal, it may be known that in many steam-boiler plants of the country, that of the latent efficiency in the coal, something less than 6 per cent. is turned into useful work, 94 per cent. being wasted. The best steaming practice is that of the Interborough Rapid Transit Company of New York, or the Commonwealth Edison Company of Chicago, by which as much as 10 per cent. of the latent efficiency of the coal has been converted into useful work. The waste has been very carefully analyzed and is distributed about as shown in the diagram:

	Heat Units.
Put in the furnace, about	13,500
Lost in the ashes	135
" " boiler radiation	675
" " steam	10,500
" " pipe radiation	210

A certain percentage is lost in delivery to the auxiliaries and in the exhaust; a large proportion goes up in the gases through the chimney—2970 B.T.U.; there are delivered to power 1273 B.T.U.; there are rejected to the condenser 103 B.T.U., until finally there are delivered to the belt only 1171 B.T.U.

Of the very large loss shown as going up the stack, there are visual evidences in the carbon of the pall of smoke hanging over our cities, and it is known that there are greater losses in the unconsumed gases. The engineers of the Survey, after an investigation of something like 280 of the best power plants of the country, and after making many tests of the Survey fuel plants, with practically every coal available in the United States, have found that nearly all can be burned in some form of apparatus without the production of smoke, and consequently without the loss of carbon in the smoke and in the gases, and with an increased efficiency and a reduction in amount of coal used.

In Pittsburg, to show the possibilities of smokeless combustion, and also for economical reasons, the Survey is buying the worst coal it can get. The contract last year was at 88 cents per ton for coal delivered in Pittsburg. This year it is $1.10. It is now being burned smokelessly under two 210 HP. boilers and other smaller boilers.

Now, in the smoke that goes up the chimney there is a pretty clearly defined relation between the percentage of black smoke—increasing from 0 to 50—and the percentage of carbon monoxide in the flue gases, so that there is lost up the chimney not only carbon, but unconsumed gases. There is a similar relation between the percentage of black smoke going up the chimney and the unaccounted-for losses through the stack, thus showing that it is an undoubted economy not to produce smoke.

An illustration is a hand-fired boiler with baffling between the tubes and a given arrangement of baffle walls in the combustion chamber, so as to give the volatile matter driven from the coal a long road to travel, and thus cause it to mix in such a manner with the air as to produce practically complete combustion before the hot gases strike the cold boiler-tubes and are caused to deposit soot or carbon by the reduction in their temperature, and thus cause smoke from the chimney.

By such expedients the mechanical engineer is able to take a furnace—I do not say boiler, because that is probably all right—and operate it in a way so as to give such a course of travel for the gases to the chimney that they will be properly consumed before they have an opportunity to reach the outer air. He can so manage the draft, either forced or natural, and the stoking, either by hand-firing or mechanical means, as to produce a more efficient combustion of the fuel with less loss.

The government has in Pittsburg a very extensive plant for fuel testing, consisting of a number of large buildings, transferred to the Geological Survey by the Ordinance Department of the army. In one of these buildings, 210 feet long by 50 feet wide, all the heating is done by means of different types of house-heating boilers. This investigation is going on continuously at the request of the Quartermaster's Department of the army, which has to supply heating plants for military posts throughout the United States, and to contend with any of the fuels which are locally available, and where they may have anything from the little house-heating boiler for the officers' quarters up to the large boiler in the barracks, or a larger return

tubular boiler in a hospital building or a large barracks. Here shipments of coal purchased by the Quartermaster's Department are received from all parts of the country, in amounts of 2000 pounds for each shipment, and tests are made of it in different types of boilers and with that type of firing which will produce the greatest efficiency from the cheapest coal available.

There are some interesting relations between the volatile matter in the coal and the efficiency of house-heating boilers, which are of particular concern to the people in the central part of the country where they have the volatile coals, such as those of Indiana, Illinois, and Iowa. For instance, the volatile matter in the combustible has ranged in a series of tests from 18 to 22, 34, 38, and 44 per cent., and as the volatile matter increases from 18 per cent. to 44 per cent., so does the efficiency decrease in percentage, owing to the fact that much of the volatile matter passes out of the stack unconsumed, the efficiency being 60 per cent. with a coal containing the least volatile matter, and diminishing to 47 per cent. for the coal having the greatest amount of volatile matter. The percentage of black smoke bears out the statement just made, to the effect that with the lowest volatile matter there is the lowest percentage of black smoke—18 per cent.; and with the highest, 44 per cent., there is over 33 per cent. of black smoke.

There is a similar relation between the percentage of CO_2 and the CO in the dry flue gases, showing that the uncombined gases are carried out with the smoke in the same proportion.

Realizing that there is a certain critical length of travel for the volatile gases driven off in heating coal, for each type of coal, at which the highest efficiency will be produced, the Survey has constructed what is called a "long combustion chamber"; namely, there has been built out from one of the 210 HP. boilers a furnace or combustion chamber of absurd length, 40 odd feet, so as to get the maximum length of travel for the flue gases and afford them an opportunity to mix with the air, and in this is being studied the behavior of these gases. There is a mechanical stoker and the combustion chamber is made semi-arched. It is well insulated, being lined with fire-brick, and then there is an air-space and an outer lining of common brick, and that feature has developed some important facts. At every five feet along the length of this chamber are peep-holes through which pyrometers may be inserted to take temperatures and for gas sampling. There are some similar holes

in the top. It took from six to nine months to calibrate this apparatus, find out how to sample the gases, and take temperature measurements and get results which are comparable. For every slight variation in feed and draft there is a different method of travel of the gases, and consequently the samples differ at different points in the apparatus. Ultimately simultaneous temperature measurements and samples were taken at different cross-sections to get accurate calibration. Gas sampling is now done through a cross-section by inserting tubes, one set arranged vertically and one horizontally, and simultaneous samples are thus taken, removed to the laboratory, and analyzed.

To determine the rates of conductivity of heat through the walls of the furnace, thermo-couples were rigged up at different points in the sides. These have developed some interesting facts relative to heat conductivity in furnace walls. The air-space between the outer brick and the fire-brick lining does not form as good an insulator as was at first believed. The air is stagnant in there and does not circulate, and the outer side of the fire-brick, that is, the side next to the air-space, and the inner side of the outside common brick wall, that is, the side next to the air-space, have practically the same temperatures, while there is a marked drop in temperature through the fire and common brick walls. If the air-space were filled with some insulating material, such as mineral wool or sand, a better insulating effect could be had.

Another apparatus for determining the best use to which to put a certain coal is the producer gas plant, and each of the carload samples was tested in the gas-producer as well as in the steam plant.

For the information of those not familiar with the action of a gas-producer, it may be stated that from the producer the gas passes through an economizer and a scrubber, and finally into the gas-engine and the losses are similar to those of a steam plant. About the same percentage of efficiency is lost in the ash-pit, but much less than in the steam-boiler; about 20 per cent. is lost in radiation and cooling, and a certain amount in pipes and in friction, until ultimately there is delivered to the belt in power an average of 13.5 per cent. In other words, a considerably larger percentage of the latent energy in any particular coal is converted into power in the gas-producer than in the steam-boiler.

The pressure gas-producer is designed not only to use anthracite and coke, but it may be so manipulated as to run on the most volatile

bituminous coals, lignite, and peat. In the Survey testing plant no difficulty whatever is experienced in operating gas-producers on long runs of a week on any fuel. Recently a test was run on Rhode Island coal, almost a graphite, from a field abandoned for years because it was considered of no value for steaming, yet it developed the full load of the engine on a four-day run, with practically no clinkering and very little ash. As for peat, a run on 40 tons of Michigan peat is now being made.

The depth of the coal-bed in the producer is 6 to 8 feet. The distillation zone has a temperature from 700° to 1300° F. The decomposition takes the form of breaking up $CO_2 + C$, resulting in $2CO$ and $H_2O + C$, resulting in $CO + H_2$ at a temperature of about 1900° F. The combustion zone lower down has temperatures about 2000° F. There are holes in the side of the producer, as in the long combustion chamber, for taking pyrometer measurements and gas samples from all portions of the fuel-bed, and by this means some interesting things have been discovered which will have an important development on the future design of producers. These results show the things that are detrimental to efficiency; dead spots and sluggish action in travel of the gases, and low temperatures along the edges. The chemists have found CO_2 being produced in the cooler portions where CO might be produced, and that the proper reactions are not carried on because the proper temperatures are not maintained throughout the producer. Through slight changes it is believed that ere long, with this knowledge, it will be possible to get much greater efficiency from the gas-producer than now.

A comparison of coal from different parts of the country when converted into energy through the steam-boiler is very interesting. The gas-producer, when operated in the very best way with Virginia coal, produced 3.3 times as much efficiency as a steam-boiler of the best type operated in the best way in testing practice. Likewise for certain Pennsylvania coal we get a ratio of 2.8 times the efficiency with the gas-producer as against the steam-boiler.

Using the best West Virginia coal under the steam-boiler, and the lowest grade of lignite in the gas-producer, the poorest grade of coal produced about the same efficiency, that is, the same number of electrical horse-power, in the producer gas plant as did the best steaming coal used under the boiler.

On the average, taking the poorer grades of commercial plants throughout the country, there are 95.2 per cent. losses in the steam

plant, and about 4.8 per cent. useful energy, as against 86.5 per cent. losses and 13.5 per cent. useful work in the producer gas plant.

It is evident from these figures that there is great room for more efficient use of our coal-supply, and if you think it over, up to within the last few years, since the development of recent improvements in mechanical stokers and drafts, there was for a century almost practically no improvement in the method of converting coal into steam for power, and hardly any diminution of the losses. Now that the attention of the country has been turned to this question of efficiency losses in the conversion of the energy of coal into power, it is quite readily believable that as soon as engineers find it to their advantage to get to work and think on this problem, we may hope for decided improvement along this line. The mere saving of 5 per cent. of the latent energy in the fuel would mean an increase of 100 per cent. in the work we are getting out of our coal, and that would mean a prolonging of the life of the coal fields, if used for power production alone, to double its present prospective length of life.

The kinds of coal which are not of much use otherwise are converted at the testing station into hard compact lumps—"briquettes," as they are called. The pulverized coal is usually mixed with some binding material, generally coal-tar or water-gas tar, and then it is pressed in a machine something like a brick-making machine. These briquettes burn almost like anthracite. Instead of puffing up, they burn slowly from the outside and hold their shape. A great many combustion tests have been made on them in many types of furnaces. The cost of the binding material is quite an item. A machine at the Pittsburg plant successfully briquettes lignite without a binder.

At the coke-testing plant of the Survey there have been tested about fifty different possible coking coals. Some of these were treated by washing, to get rid of the superfluous ash and sulphur. Coals which were supposed to produce a coke not of much value in metallurgic processes, were, by a proper study of what they needed in the way of washing, converted into good coke.

Another question before the Survey is how to prevent so-called mine accidents, not how to rescue the men in the mines after the accident. The government is not engaged in rescue work and has no authority under the law to engage in it. That is work of the state inspectors. All the federal government can do is to investigate, and disseminate information. The Survey investigates mine disasters

with a view of determining how they may be minimized, and incidentally to doing that, it has developed that the best way to find out the causes of mine disasters is to go into the mine right after the disaster has taken place, and study the same at first hand, while it is possible to get the temperatures as they are then; and before ventilation has been turned on, to get samples of the gases, and, in short, to study the conditions before operations have been resumed. It was found that this could be done only by the use of some artificial breathing apparatus, so that while the men went into the mines after disasters merely as students, and the state mine inspectors and mine-owners were waiting to get into the mines, or, that is, waiting for them to become safe for human life, there was forced upon the Survey engineers the need for their assistance in rescuing those who were caught below.

In regard to rescue work, the government engineer is frequently called upon for advice, which is given freely, but he has no authority to direct what shall be done.

In the beginning of the inquiry into mine accidents it was found that the death-rate in coal mines in the United States was on an increasing ratio. In 1895 there were about 2.7 persons killed per thousand employed in the mines, and the ratio has gradually increased to 1907, when it was about 3.3 persons killed per thousand. Great Britain, where years ago they undertook to investigate the disasters in mines and to develop methods of protecting the lives of miners, from 1860 to 1895 had less than half the number killed in the United States. We are killing 3000 men a year and maiming or injuring a great many more. Great Britain now has her ratio down to a little above one per thousand. The Belgium mines are naturally the most dangerous to work in the world. Belgium has made the most progress in the reduction of mine accidents and remedial measures: In 1880 it had a ratio of 3.3 killed per thousand, and now it has something less than one per thousand killed.

Of the appropriation for mine accident investigations 90 per cent. is spent in Pittsburg in laboratory investigations, and the other 10 per cent. is spent in substations in different parts of the United States. From these stations men are available to go into the mines and study them and learn something about the methods of mining coal, so that reports and information may be disseminated which may be valuable as a guide to miners and mine-owners.

The principal piece of apparatus in Pittsburg is a miniature mine

gallery 100 feet long and about 6 feet in diameter, having openings along the side at about every 6 feet and pieces of plate glass through which the travel of the flame from an explosion can be watched. One end of the gallery opens into the air. The other end is fastened in concrete in which is embedded a cannon. In this cannon is placed a sample of the explosive found in a certain coal mine. This is fired and the effect noted in the gallery. As a result of these tests, certain facts have been developed and certain information gathered which is undoubtedly going to have an influence in reducing the loss of life in coal mines. All the explosives found in the mines have been tested by detonating them in the presence of known amounts of coal-dust, the amount fixed by calibration, practically a pound per foot, to simulate the way it may occur in the mines, and in the presence of mine gases consisting of known percentages of methane mixed with air by a fan. In the beginning it was found that so-called "safety" explosives would detonate the gas or dust and cause an explosion, and that certain other explosives would not. At first there were few explosives on the market which would not ignite an 8 per cent. mixture of mine gas in air and which would not cause an explosion of coal-dust. The manufacturers, as the result of the record of these tests, quickly produced the kind of explosive wanted, so that last May it was possible to issue an official list of "permissible" explosives, or of those considered safe for use in gaseous and dusty coal mines. The American tests are somewhat more severe than those of any other country, yet since May there have been developed so many more permissible explosives that there are now thirty-one that have been passed, and the manufacturers are making others just a little better, and applications are now in for testing up to forty-six.

The greatest mine disasters in this country have been produced by coal-dust explosions. When mine gas is ignited, the explosion is local in that part of the mine where the gas is exploded. An explosion of coal-dust is greater at the end of a thousand feet than at the beginning. Such is the kind of mine disaster that occurred at Monangah, West Virginia, a few years ago.

DISCUSSION.

Carl P. Birkinbine.—How does Texas lignite compare with the lignite from North Dakota?

Mr. Wilson.—I cannot say that there is sufficient difference to be worth mentioning. We found that with Texas lignite, and six carloads from California and some from North Dakota, we were able to briquette one about as success-

fully as the other. So far as gas-producing qualities are concerned, they are about equal. There are slight differences, not sufficiently pronounced for me to recall them.

J. C. Trautwine, Jr.—How do you account for the fact that the intensity of the explosion increases with the distance through which the explosion has to travel?

Mr. Wilson.—It is accounted for first because there is more dust blown into the air by each succeeding detonation, the action being that of a succession of explosions. At the point where the explosion begins only a small percentage of the dust is ignited, but this is rapidly added to and the volume is increased until all the dust, from one end of the chamber to the other, is within the detonating zone. Like cement manufacture, a great deal depends upon the fineness of the dust. The first explosion ignites the dust, and as it progresses it ignites the remaining dust, and so gathers force to the end of the mine gallery.

President Dallett.—Do you not think rather that the intensity of the explosion is due to the compression? If you take a mixture of coal-gas and air and explode it under atmospheric pressure, as the original explosion takes place the intensity of the explosion is much less than where you have a high compression to start with, and as the explosion travels on, you get a higher compression than at the point where the explosion takes place.

Mr. Wilson.—Undoubtedly so. The Survey is publishing a bulletin describing tests of the explosibility of coal-dust. It shows the tests made in the gallery to determine methods of moistening the dust, or mixing with shale-dust, or mixing it with calcium carbide to deaden its effect. We found you could wet it with almost 30 per cent. of water and it would yet explode under favorable conditions; even dampening it does not always make it a non-explosive. What is wanted is to maintain in the mine conditions similar to those present in the humid and warm days of summer. You may have noticed that the coal-dust explosions nearly all occur in the early winter. We rarely have them in summer. The mine is dried by ventilation in the winter, whereas in summer-time it is not so dry. How to drive air into the mine, commerically, so as to keep its temperature and humidity fairly uniform in the winter as in summer is the question. This is fully set forth in the bulletin referred to.

P. A. Maignen.—After one of these explosions is there any CO_2 present, or CO?

Mr. Wilson.—Methane is present in large quantities; frequently CO, but more CO_2.

Mr. Maignen.—Does it come from the explosion or from the mine gases?

Mr. Wilson.—It comes from the explosion of the mine gas or coal dust, the analyses of which have shown in some cases as low as 10 per cent. of O after some explosions and a pretty high percentage of CO_2.

Mr. Maignen.—If the CO_2 were present in some way or other, would that improve the case?

Mr. Wilson.—In most cases we have known there was not enough oxygen to sustain life and the amount of CO_2 present would doubtless produce death.

E. M. Nichols.—Is there any loss in value between briquetted coal, taking into consideration the cost of briquetting, and run of mine coal?

Mr. Wilson.—I do not believe we know enough about briquetting yet to

know in many cases whether it is commercially a paying proposition. Everything depends upon the price of coal at the mine and the success of the owners of the plant in keeping it in constant operation. At a plant like our testing station we have a let-up of a day or two while fixing up the machinery, and then have a good long run of six, eight, or ten hours' operation. We find that many of the cheaper grades of coal can be briquetted at a price which is profitable. If the mine is near a railroad, say in Missouri or Arkansas, and you get the coal at the mine at eighty cents or a dollar per ton, and the briquetting process costs $1.50 a ton, the whole costs $2.50 a ton, and will compete very favorably, at that point, with coal coming from Illinois that costs $3.50 per ton. That is the condition. If you can briquette it at such a price that it will produce a fuel which is worth $2.00 or $3.00 a ton, which will compete with a better grade of coal of higher price, it will be profitable.

Dr. H. M. Chance.—Is anthracite dust as liable to explosion as bituminous dust?

Mr. Wilson.—No. I was present on two occasions where anthracite dust was used, but no explosion was produced under conditions which would have ignited bituminous dust. Doubtless anthracite coal-dust will ignite under favorable conditions.

Dr. Chance.—Another phase of the matter has occurred to me, and that is the accuracy with which the B.T.U. determinations can be made. In looking up the records of some tests, I find that in the calorimetric tests the units were only taken to the third place; that is, 2.54. Sometimes I believe they read to thousandths, which would be one part in 10,000. How accurately, or how close, would you expect two determinations to check made by your own men, say each taking his own sample, and letting the determinations be made entirely separately—what would be the expected comparison of the B.T.U.'s?

Mr. Wilson.—I do not think you can rely upon any single calorimetric determination being within much under 50 B.T.U.'s. Taking as we do a number of determinations and averaging them, I think we can readily report them down to 10 B.T.U.'s. We do not think it is worth trying to get nearer than 50. As a rule, we have found the trouble is that commercial chemists use coal for calibrating their apparatus, and that is absolutely impossible as a calibrating material. We use sugar or some pure carbon substance like that.

Dr. Chance.—I imagine the calorimeter is more accurate than the sampling. Where duplicate samples are taken of the same shipment by different samplers, I would like to ask what variation is found in B.T.U. determinations.

Mr. Wilson.—You can get very wide differences in determinations in sampling. The only thing we found possible was to have an established method of sampling which is taught our inspectors, and we find we can get fairly uniform results from samples taken by two men trained in the same methods of sampling. When we sample the deliveries, there is a reasonable accord, although it will not stand comparison with sampling by others. The getting of samples is one of the questions now requiring the most careful inquiry and study.

Dr. Chance.—What I would like to know is how nearly the sampling of the same shipment made by two men trained by the department in the same methods of sampling would check.

Mr. Wilson.—With high-grade coal we will get very close accord, and with

poorer grades we have wide variations, because the slaty matter is distributed unevenly in the car and in the various sized lumps composing the carload. We often have some trouble with the laboratory samples. After we get the specimens parted down to 4-pound samples and then begin to grind it, even for laboratory samples we have some difficulty.

A. E. Lehman.—What is the method of sampling from large and small shipments, say with carload lots?

Mr. Wilson.—Our largest car sampling is for coal delivered to the Panama Canal. There are two ships a week going there. We tried sampling every tenth car, and then every fifth car. Our method is for a man to stand by with a scoop and accumulate a large sample of a ton or more, then spread it on a blanket and mix it up, quarter it, and then pass the quarter through a sampling machine, which is a bucket with a vertical compartment in it; and then it drops through another bucket which parts it again, and so on until we get it down to a laboratory sample.

S. E. Fairchild, Jr.—How about the lumps in the middle?

Mr. Wilson.—Well, that depends upon the sampler himself. As he uses his scoop he tries to get as much lump in one sample as in another. We have experimented until we have gotten down to a fairly uniform method of sampling. The big dealers have their own men on the wharf, and if they can trip our people up, they are going to do it, yet we have had no complaint, and I think we are working nearly uniformly in that direction. We have checked samples in the mines and in transit, getting a sample in the mine and getting another from the same car at the wharf, and in that way we get data on the loss or increase in moisture in transit, and the increase in ash, etc.

Dr. Chance.—The sampling and buying of coal along these lines is getting to be quite a fad. I think the reason things are working so smoothly between the contractors and the bidders is that the bidders understand the methods adopted by the government, and in that way things work out all right, but it does not follow that the results are truly representative. To do it right might cost $10 a ton, or ten times more than it is worth. On large contracts it might be true economy to adopt these methods and incur the labor and expense, but in the purchase of coal in small quantities I think it is absolutely impossible to carry out this plan without involving an expense many times the value of what would be gained. I would like to ask Mr. Wilson as to the personal equation between two different samplers as found by actual practice in sampling, say in sampling the same coal by the same method. I have had a number of cases of that kind myself and have never been able to get satisfactory results. The same men will get different results at different times even when using the same method of sampling.

Mr. Wilson.—I agree with what the speaker says, but I cannot answer him satisfactorily now. I will be glad, however, and will with a great deal of pleasure answer all communications in the greatest detail, if you will give me the details of some particular case.

I doubt if this method is profitable for small consignments. For the government, however, we find it profitable on some of the smallest deliveries, whereas it would not be profitable for small consumers; that is probably because we have inspectors who are available and have a laboratory, etc.

The navy yard at Washington agreed to have its buckwheat anthracite

purchased on the B.T.U. basis, and the samples were analyzed by us. After we first started in, the penalties were so heavy that the contractor was up in the air, as they say. We did the best we could for him and told him how his coal was running; he claimed that he was sending word back to his operator and that they could not do any better, and another contractor who was delivering 7500 tons was having the same trouble. The coal was running about 22 per cent. ash. Inside of a few weeks their coal was down to 16 per cent. ash, which they have been delivering steadily since. They found just where their coal was coming from and are now delivering it according to specifications.

ABSTRACT OF MINUTES OF THE CLUB.

Business Meeting, November 6, 1909.—The meeting was called to order by the President at 8.40 P. M., with 179 members and visitors in attendance. The minutes of the Business Meeting of October 16th were approved as printed in abstract.

The President announced that at a meeting of the Board of Directors, on November 1st, the resignation of Mr. Philip L. Spalding as vice-president of the Club had been accepted, that Mr. Henry Hess had been elected vice-president to fill Mr. Spalding's unexpired term, and Mr. W. L. Plack elected member of the Board to fill the unexpired term of Mr. Hess.

Following a report of the tellers on the election of members, the President declared that Thomas Hugh Boorman was elected to Active Membership, and that Herbert McMillen Dibert, Harold Goodwin, Jr., Clarence Bayne Kelley, and James Clawson Roop were elected to Junior Membership.

The following report was then presented by the tellers on the ballot for the amendment to the By-Laws increasing the dues of Resident Active and Associate Members from $25.00 to $35.00 a year: For the amendment, 190; against the amendment, 79; necessary for approval, 179, the amendment thus being carried by 11 votes.

Mr. A. M. Herring, visitor, presented the paper of the evening, entitled "A Few of the Engineering Problems Involved in the Design of the Aeroplane." Following the paper, moving pictures were exhibited, illustrating the flights of various types of aeroplanes at Rheims.

Upon motion of Mr. Swaab, a vote of thanks was extended to Mr. Herring for his extremely interesting paper.

Upon motion, the meeting adjourned at 11 P. M.

Business Meeting, November 20, 1909.—The meeting was called to order by the President at 8.35 P. M., with 105 members and visitors in attendance. The minutes of the Business Meeting of November 6th were approved as printed in abstract.

The President announced the death of Mr. George T. Barnsley, President of the Engineers' Society of Western Pennsylvania and Active Member of this Club. Mr. Barnsley's death occurred on October 23, 1909.

The Committee on Nominations reported as follows:

For President (to serve one year)—Wm. Easby, Jr.
For Vice-President (to serve three years)—Charles Hewitt.
For Secretary (to serve one year)—W. Purves Taylor.
For Treasurer (to serve one year)—E. J. Kerrick.
For Directors (to serve three years)—David Halstead, J. A. Vogleson, Percy H. Wilson, F. K. Worley.

Mr. H. C. Berry, Active Member, presented the paper of the evening, entitled "The Rating of Pitot Tubes for Use in the Test of a Niagara Power Plant," which

was discussed by Messrs. Wm. Easby, Jr., W. M. White, John C. Trautwine, Jr., and others.

Upon motion, the meeting adjourned at 10.30 P. M.

Business Meeting, December 4, 1909.—The meeting was called to order by the President at 8.40 P. M., with 143 members and visitors in attendance. The minutes of the Business Meeting of November 20th were approved as printed in abstract.

Following a report of the tellers, the President declared that Horace G. H. Tarr was elected to Active Membership and James Morgan Harding to Junior Membership.

Dr. Henry Leffmann, Active Member, presented the paper of the evening, entitled "Diamond Mining," which was informally discussed by Messrs. John C. Trautwine, Jr., John C. Parker, S. M. Swaab, Wm. Easby, Jr., James Christie, Wm. C. Furber, H. C. Snook and Frank Burns.

Upon motion, the meeting adjourned at 10 P. M.

Business Meeting, December 18, 1909.—The meeting was called to order by the President at 8.35 P. M., with 121 members and visitors in attendance. The minutes of the Business Meeting of December 4th were approved as printed in abstract.

The President called to the attention of members that "Club Nights" would in the future be held on Thursdays, instead of Fridays.

Mr. Herbert M. Wilson, visitor, presented the paper of the evening, entitled "Government Investigations and Tests of Fuels." At the close of his paper Mr. Wilson also described the work of the government in connection with the prevention of mine disasters. Messrs. Carl P. Birkinbine, John C. Trautwine, Jr., P. A. Maignen, E. M. Nichols, H. M. Chance, A. E. Lehman, S. E. Fairchild, Jr., Francis Head and others took part in the discussion. Upon motion of Mr. Head, a vote of thanks was extended to Mr. Wilson.

The meeting adjourned at 11 P. M.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

REGULAR MEETING, November 1, 1909.—Present: President Dallett, Vice-Presidents Devereux and Easby, Directors Clarke, Head, Quimby, Twining, Christie, Cochrane, Hess, Gwilliam, Hutchinson, Mebus, the Secretary, and the Treasurer.

Mr. Spalding's resignation as Vice-President of the Club was read and accepted, and Mr. Henry Hess was elected Vice-President to serve the remainder of Mr. Spalding's term, expiring February, 1912. Mr. W. L. Plack was then elected a member of the Board of Directors to fill the place of Mr. Hess, term expiring February, 1911.

The resignations of David Pepper, Jr., and E. J. Hasse were read and accepted, as of even date.

It was moved and carried that the House Committee be authorized to organize a movement toward the development of the social side of the Club, and that it be empowered to give entertainments, to appoint suitable committees, and otherwise act in this matter as seemed most expedient.

Upon motion, the meeting adjourned, to continue on Monday, November 8, 1909.

ADJOURNED REGULAR MEETING, November 8, 1909.—Present: President Dallett, Vice-Presidents Easby and Hess, Directors Twining, Cochrane, Gwilliam, Hutchinson, Mebus, the Secretary, and the Treasurer.

Letters from Mr. Henry Hess and Mr. W. L. Plack, formally accepting the offices of Vice-President and Director, were read.

The resignation of Mr. H. E. Hutchins was read and accepted, to date from December 30, 1909.

Following an informal discussion of Club affairs, it was moved that a committee of three be appointed to formulate and draft schemes for the improvement of the Club-house, and to present the same to the Board.

REGULAR MEETING, December 4, 1909.—Present: President Dallett, Vice-Presidents Devereux and Easby, Directors Clarke, Head, Quimby, Twining, Christie, Cochrane, Develin, Plack, Gwilliam, Hutchinson, Mebus, Wood, the Secretary, and the Treasurer.

The Treasurer submitted the monthly statement of the accountants, and reported that a loan of four thousand dollars for sixty days had been negotiated with the Colonial Trust Company.

Upon recommendation of the Committee on Membership, the following members were advanced in grade:

From Associate to Active: Houston Dunn.

From Junior to Active: Wayne B. Morrell, Edwin S. Young, Francis R. Berlin, H. R. Wilkinson, Edward M. Bassett, Frank H. Rogers, Edward E. Krauss, John N. Costello, Gordon Brandes, Lesley Ashburner, and Henry E. Birkinbine.

From Junior to Associate: Wilbur E. Fawcett.

The following resignations were read and accepted as of December 31, 1909: Edward B. Myers, H. R. White, John W. Townsend, Harry H. Cooke, Harry W. Jayne, J. Livingston Poultney, Joseph Johnson, Wm. C. Williamson, Herbert Hollick, J. Max Bernard, and Clark Dillenbeck.

It was moved that the regular meeting of the Club, falling due on January 1, 1910, be postponed until the following Tuesday, January 4th.

A letter from Mr. H. F. Sanville, Chairman of the Committee on Increase of Membership, recommending certain changes in the By-Laws, was read, and referred to a special committee, consisting of R. G. Develin, Chairman, J. O. Clarke, Wm. Easby, Jr., W. S. Twining, and H. F. Sanville, to report at the next meeting of the Board.

The rules for the government of the Board of Directors were referred to the Secretary for revision and presentation at the next meeting of the Board.

Following an informal discussion of the affairs of the Committee on House, it was moved that plans and estimates for changes in the location of the offices be obtained and submitted at the next Board meeting.

It was also moved that the House Committee be authorized to make changes in the lighting, provided the expense of such changes did not exceed $200.

The President appointed Mr. W. L. Plack an additional member of the Committee on House.

SPECIAL MEETING, December 18, 1909.—Present: President Dallett, Vice-Presidents Devereux, Easby, and Hess, Directors Clarke, Head, Quimby, Christie, Cochrane, Develin, Plack, Gwilliam, Mebus, Wood, the Secretary, and the Treasurer.

The following resignations were read and accepted as of December 31, 1909:

Active: E. M. Bassett, Francis R. Berlin, J. W. F. Blizard, Wm. H. Butler, Jr., H. D. Fischer, Caspar W. Haines, Chas. E. Machold, Edwin F. Miller, and Harry M. Platt.

Junior: Harry H. Appleton and Donald Graham.

The Committee on House presented its report on certain proposed changes in the Club-house, but action in the matter was deferred until after the first of the year.

The treasurer presented the monthly statement of the accountants, and reported on the present financial condition of the Club.

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PROCEEDINGS

OF

THE ENGINEERS' CLUB

OF

PHILADELPHIA

Edited by the Publication Committee

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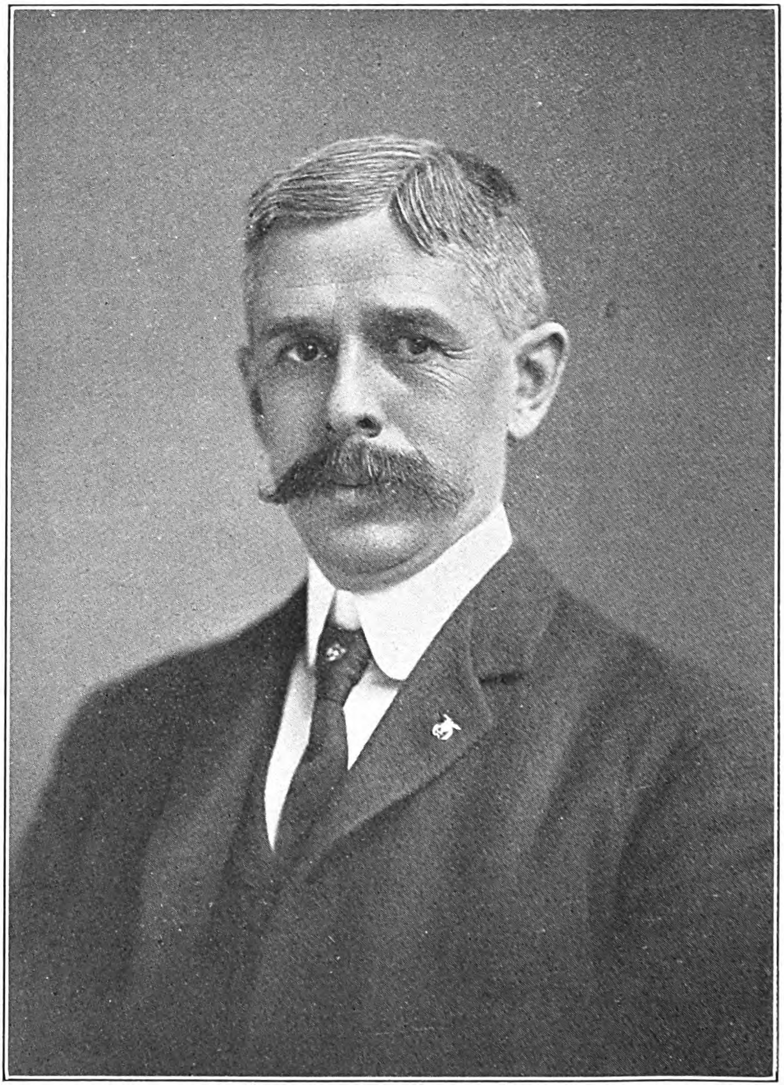

William P. Dallett
Thirty-second President of the Club, January 16, 1909, to February 5, 1910.

Editors of other technical journals are invited to reprint articles from this journal, provided due credit be given the PROCEEDINGS

PROCEEDINGS

OF

THE ENGINEERS' CLUB

OF PHILADELPHIA.

ORGANIZED DECEMBER 17, 1877. INCORPORATED JUNE 9, 1892.

NOTE.—The Club, as a body, is not responsible for the statements and opinions advanced in its publications.

Vol. XXVII. APRIL, 1910. No. 2

PRESIDENT'S ADDRESS.

WILLIAM P. DALLETT.

Annual Meeting, February 5, 1910.

FOLLOWING the time-honored custom inaugurated by the first President of this Club thirty-one years ago, it is my privilege and duty to address you at this time. As he fittingly called his address "the last chapter in the first volume of our history," so this will be the last chapter in the thirty-second volume.

It is a pleasure to congratulate the Club upon its thirty-two years of practically uninterrupted prosperity in its ever widening field of usefulness. There have, of course, been periodic depressions in the lines representing membership, finance, attendance, etc., but the general tendency of all these lines has been constantly upward.

The slight loss in membership during the past year has no doubt been in a measure due to the depression in general business, and also to the fact that the Club has just passed through its second summer of new Club life. Second summers in club, as well as in human life, can be considered as precarious periods, and the present healthy condition of the Club at the end of its second year in the enlarged sphere of Club life is certainly gratifying.

There has been a marked increase in the use of the Club-house at times other than on regular meeting nights. This increased interest of the members in the Club is showing results in the number of applications for membership that are being received, with every indication that a material growth may be expected during the coming year.

It is not my intention to-night to attempt any comprehensive review of the engineering or construction events of the past year, but rather to note some of the more or less prominent ones, and some of the developments that have taken place in the past two or three decades.

I am well aware that in matters reminiscent the older members of the Club have a much larger fund of information than I have, while on matters of the present day you are all so well informed through the medium of the technical, semi-technical, and popular press that a review at this time seems unnecessary, but thirty-two years ago no such criticism could have been advanced, for both technical and popular publications were meagre as to size and number.

Conservation, a legacy from the strenuous ex-President of the United States, is, at the present time, very prominently before the public. In fact, a large proportion of the people look upon it as something which he invented or created, and, in so far as this applies to departmental reforms in disposing of and developing the natural resources that remain in the hands of the national government, he certainly deserves the credit for the institution of such reforms and the agitation along the general line of conservation.

Congressional investigation is being made at the present time which may result in saving to the nation for its future welfare a vast amount of nature's resources that might otherwise have been appropriated without adequate remuneration.

Conservation, however, does not apply only to nature's resources remaining in national control. In its broad sense it covers the conserving, in the most economic way, of all nature's resources to the uses of mankind in the preservation of life and in promotion of health and happiness.

In every problem, no matter how trivial, the engineer finds himself face to face with the question of conservation; he has to decide how he can best achieve the desired ends with the most economic use of the forces at his command. In the design of a power generator, he must promote conservation by the most economic use of nature's resources, be they either the flowing river or the bottled up sunshine of ages. In the conversion of power into electricity or electricity into light, if the engineer is to succeed, conservation must be his aim. In the building of bridges, canals, ships, high buildings, tunnels, or in any of the thousands of questions the engineer is called upon to solve, conservation must be his guide. All of them must be built

with economy, operated with economy, and designed to protect human life and health and to promote happiness by conserving human exertion and time.

In so far as the engineer succeeds in the promotion of conservation, just so far does he succeed in the carrying out of the ideals of his profession.

This is preëminently an age of mechanical power. Wherever we look we see it supplanting all forms of physical exertion. We need go back little more than a half century to find practically all the labor on the farm performed by human energy. The introduction of machinery operated by animal energy was a stride in the line of conservation.

The mowing machine, the churn, the thrashing machine, the planter, the cultivator, and the more complicated reaper and binder, all operated by animal energy, have rapidly supplanted the earlier and more laborious methods of performing the same work. These in turn are being supplanted by more efficient machines driven entirely by mechanical energy.

On the modern farm you will find that the gasoline engine has supplanted the treadpower and the sweep. The automobile has already supplanted the lighter vehicles, and is rapidly supplanting the heavier ones. All the minor chores of the farm are being done by some form of mechanical motor, and even house-cleaning is done by mechanical power.

We also find the horse-car of twenty years ago supplanted by the cable car, and it in turn supplanted by the electric car. The sailing vessel has practically been supplanted by the steam-propelled craft, be it the tramp steamer or the palatial liner attempting to cut a few hours off the already marvelously short trans-Atlantic trip.

Thirty years ago the streets of Philadelphia were entirely without electric lights, and when in 1883 forty-nine experimental lights were placed in Chestnut Street, the public press predicted total blindness of the coming generations on account of the brilliancy of electric light. In fact, twenty years ago there were barely 1000 electric street lights in the entire city, while to-day an accurate estimate would be indeed difficult to make and still harder to believe, the growth having been so rapid and enormous.

Mechanical refrigeration has practically supplanted the use of natural ice. Locomotives have increased in size from a few tons to over two hundred tons. Textile mills and other manufactures are

increasing their power daily on account of the elimination of manual labor or the introduction of more efficient machinery.

In these, and in thousands of other instances, the same rapid development in the use of mechanical power could be noted. Power seems to be the keynote of our existence—the very base of our civilization. In all this development of *power*, the hand of the engineer is seen in the ever-increasing higher efficiency, and, in many cases, this increased efficiency assumes no mean proportion.

In electric lighting to-day, as distributed from our most efficient lighting plants, a pound of coal will furnish approximately 400 candle-power hours in the home of the consumer, while, twenty-five years ago a pound of coal, under the then existing conditions of central plants and incandescent lamps, would have furnished only fifty candle-power hours. The ordinary gas burner of thirty years ago produced approximately three candle-power per cubic foot of gas consumed, while to-day we hear reports of thirty candle-power for the same consumption.

Other instances could be named of equally great strides in the economic use of fuels, showing that the engineer is ever working for conservation. It might be presumed that, on account of these economies, the consumption of fuels would have decreased, but the cheapening of power has created a greater demand for it rather than a demand for less coal, and the increase in the use of power has thus far been constantly in excess of the savings effected in the more economical use of coal.

The consumption of coal in the last few decades has increased not steadily but with an ever-increasing increment, so that the ultimate day of reckoning, when nature's stored energies will be exhausted, is beyond prediction. This is not to be taken in a spirit of pessimism, for that day is probably centuries off, and, as our present Executive, in a recent message to Congress, has aptly said: "No sane person can contend that it is for the common good that nature's blessings are only for unborn generations."

The weighty problem, how to best check the inroads upon nature's storehouses of energy, nevertheless remains. Will it be solved by the development of power direct from nature's sources—sunshine, wind or water? Or by the development of some form of costless power so often dreamed of? Or, will it be solved by a reconstruction of our much boasted civilization and by a return to more primitive living? Time, perhaps centuries, alone can answer; but whatever

the method, the engineer will be the means, and the answer will be conservation.

Probably one of the most important events of the year, so far as Philadelphia is concerned, and one which passed so quietly that its occurrence was scarcely noted, was the completion of the Torresdale filter plant, with a daily capacity of 240,000,000 gallons of filtered water, sufficient for the entire city. The conservation in life and health due to the filtration of the water-supply cannot be measured in dollars and cents, but expenditures greatly in excess of those already made and contemplated would have been more than warranted by the results which the statistics have already indicated, and future statistics will no doubt disclose similar results. The expenditure for all the filtration plants, including that of Queen Lane, which is under construction, and the pumping plants and the extension of distributing and force mains, will approximate twenty-eight million dollars.

The elimination of grade crossings by the elevation or depression of roadbeds, of either steam or electric roads, makes for the conservation of human life by the reduction of the number of accidents and conserves the time of patrons by shortening the running schedule. To this end the city of Philadelphia and the Philadelphia and Reading Railway are at present carrying out a most substantial and gigantic operation in the elevation of the latter's roadbed. The masonry and concrete work of this improvement are well worthy of note.

The expansion of the high-pressure fire-protection system by the erection of a high-service pumping station at Sixth Street and Lehigh Avenue, and the installation of high-service fire mains through the mill district, is a work in the direction of conservation of fire losses which deserves commendation. The original high-pressure service installation at Delaware Avenue and Race Street has proved such a success in preventing conflagrations in the hazardous central district of the city that the extension above alluded to is more than warranted.

Recently interesting papers upon the Passyunk Avenue bridge, the Walnut Lane bridge (both in Philadelphia) and the Mulberry Street viaduct at Harrisburg, Pa., have been presented before the Club. The last two, in particular, exemplify one of the many artistic uses of concrete construction. The designers in both cases have succeeded in erecting lasting monuments, not only to their engineering ability, but also to their artistic appreciation of what is beautiful.

Another bridge unique in design is the one on North Forty-second Street, West Philadelphia, over the Pennsylvania Railroad, with a span of 260 feet. It is a steel arch structure, in which the plate box girder arches have been reinforced by filling the interior with concrete. This seems to be a reversal of the general method of reinforcing concrete with steel, by reinforcing steel with concrete.

The Philadelphia Rapid Transit Company has completed its much appreciated subway, and, while this was put in operation over a year ago, the final repaving of the streets has only recently been completed. With the repaving and cleaning of Market Street, the inconveniences due to the construction of the subway are rapidly being forgotten, and it is hoped that the success which may ultimately come from its operation may induce the Philadelphia Rapid Transit Company to instal similar subways. It may be noted in this connection that New York City, after its six years of experience with a subway costing, including equipment, eighty million dollars, is now contemplating the construction of a new system, the approximate cost of which will be two hundred and forty million dollars.

The Pennsylvania Railroad has completed the construction of its tubes under the North and the East Rivers at New York City, and it is reported that the latter tunnel will be put in operation within a very few months. The magnitude of this undertaking can scarcely be conceived, much less described, other than perhaps to say that the total cost will approximate one hundred and fifty millions of dollars, and that the terminal facilities will be capable of handling a hundred million people per annum.

On July 19th the down-town tubes of the Hudson and Manhattan Railroad Company were opened to the public, making an epoch in suburban rapid transit for lower New York business men, by placing them from fifteen to twenty minutes nearer their New Jersey homes. The total saving in time to probably one hundred million riders annually is almost inestimable. The completion of these tubes and those put in service some years earlier, together with the connecting subways on the New Jersey side, and the proposed extension to the Grand Central Station at Forty-second Street, will mark the achievement of a truly great engineering undertaking. It has all been accomplished in less than ten years, with the exception of about three thousand feet of abandoned tunnel, which was acquired by the company in 1901, and which forms a portion of one of the up-town tubes. The entire system, twenty miles in length, will cost about seventy million dollars.

Passing note might be made that the year 1909 will always be marked as an epoch in aërial navigation. An immense amount of experimenting, performed by eminent scientists long prior to this, conclusively proved that heavier-than-air machines were possible. This year marks the popular achievement of actual flight, not by a single aviator, but by dozens, who have vied with each other in making records, only to be broken at the next contest. The dirigible balloon gives much promise as an engine of war.

The development of the automobile during the past year has been marked along all lines, especially in the development of heavy trucks for commercial use.

The marvelous growth of the cement industry is of particular interest to the engineer, having grown a hundredfold in the past fifteen years. In 1895 the output of the cement mills of the country was less than one million barrels, while the mills to-day have a capacity exceeding one hundred million barrels.

An event of international importance is the completion of the Trans-Andine Railway, connecting the National Railway of Chile with that of Argentina, crossing the Andes Mountains at an elevation of nearly 12,000 feet; when placed in operation, it will connect Beunos Aires with Valparaiso.

A further indication of the development of our sister republic in South America is the report that orders have been placed with American firms for two battleships of dimensions and design which will make them the most formidable war vessels afloat. The cost is said to be eleven million dollars each.

Probably no bureau in any department of the United States Government is doing better or truer conservation work than that which is being done by the Reclamation Service. While the popular idea may be that its work consists of building dams, canals, tunnels, and water-power plants for irrigation projects, a thorough investigation reveals the fact that its success is due as much to administration as to solving material engineering problems. Complicated questions concerning land and water rights have to be met, as well as those concerning power generation and distribution and the settlement and improvement of the reclaimed land. The high efficiency of the service should be a subject of pride throughout the engineering profession, particularly as it has been built up by civilian engineers and under civil-service regulations.

This bureau has just completed the Shoshone Dam, which has a

height of 328.4 feet from base to parapet, making it the highest dam in the world. This extreme height was made possible by the admirable conditions which nature provided for placing a dam at the point selected. It is located at the entrance to a canyon, the walls of which are almost perpendicular for nearly 2000 feet above the stream. In plan, the dam is curved up-stream, with a radius of 150 feet, at the top. The storage capacity is approximately 150 billion gallons and the flooded area is ten square miles.

This is but one of the many developments of the service, and in all these developments the revenues from water and power rentals repay the Government for the entire outlay within a comparatively few years.

The bureau goes even farther than this. It educates the landowner in the use of water and teaches him conservation, with the invariable result that the desert is made to blossom and bear fruit like a veritable paradise.

The engineering construction of undoubtedly the greatest international importance at the present time, one that has been prominently before the public for the last thirty years, and the completion of which will occupy the larger portion of the next decade, is the Panama Canal. It has probably been before the public for a much longer time, as no doubt the early Spanish settlers and explorers looked for some route to take their vessels to the Pacific Ocean.

The first concession granted in 1838 to a French company conveyed the right to build roads, railways, and canals. This company failed to do anything further than make a survey. A second French company, which was granted a concession in 1847, also failed, and it remained for an American company to build the railroad across the Isthmus between 1850 and 1855.

In 1876 an exclusive concession was granted a French association, which in 1879, under the influence of M. de Lesseps, decided to build a sea-level canal at an estimated cost of two hundred and forty million dollars, to be completed in twelve years. The Interoceanic Canal Company was then formed, with M. de Lesseps at its head, and it immediately entered upon the construction of the canal; but first purchased a controlling interest in the Panama Railway, to insure the validity of its concession.

The original plan for the sea-level canal contemplated the exclusion of the Chágres River from the canal through a diversion channel to be built nearly parallel to the canal. The year 1887 found the com-

pany in financial difficulty, and confronted with the fact that the canal could not be built within the estimate. A change of plan was found necessary, and one involving a temporary lock was determined upon, with a summit level of 160 feet. The company, however, failed to place its bonds, and passed into the hands of a receiver in 1889.

Five years later, in 1894, the New Panama Canal Company was formed, and resumed operations on the canal, which was to have a summit level of 102 feet. Work was continued by this company until 1902, when, with as much diplomacy as was exhibited in the purchase of this Club-house, the United States Government purchased for forty million dollars what was originally held by the French company at one hundred and nine millions; the characteristic American bluff having been worked by the commission reporting to Congress the advisability of adopting the Nicaraguan route in preference to the Panama at the figure asked. There is no doubt that a figure considerably higher than this would have been a bargain, as there had been excavated by the first French company about seventy-two million cubic yards, and by the second French company ten million cubic yards; about one-half of this total excavation was of use in the canal now under construction. There seems to be a strange coincidence in the fact that as the Panama Railway was built by Americans after the failure of two French companies, so the United States Government is now completing the canal after two like failures.

Congress, in deciding upon the type of canal after receiving the reports of an appointed board of consulting engineers, wisely adopted the report of the minority. Possibly the personnel of this minority may have had its influence, for it was composed of five American engineers, while the majority report was signed by two Americans and five foreigners.

In addition to the personnel of the minority, the arguments in favor of the lock canal outweighed those for the sea-level canal, not only in point of economy in first cost and time of completion, but also in the methods adopted for controlling and absorbing the flow of the Chágres River at times of flood; and, further, from the facts that the dimensions of the canal prism on the lock type were much more generous and the channel nearly freed from curves, thus making navigation less difficult and more rapid, notwithstanding the delay incurred in passage through the locks. Moreover, tidal locks would

have been required on the sea-level canal to control the entrance at the Pacific, where the usual tide is from 12 to 14 feet.

The cost of the canal as estimated by the minority of the board of civil engineers was placed at one hundred and forty million dollars and the time of completion at twelve to thirteen years. Since starting the work the estimated cost has been materially increased on account of some very material alterations which were made in the plans as to the size of the canal prism and locks, as well as by reason of the general advance in the cost of labor and materials, and the additional restrictions placed by Congress in enforcing the eight-hour law. From estimates now made, which are reasonably accurate, as they are based upon actual experience in executing nearly one half the work, the total cost of the American work on the canal, including engineering expenses, will be approximately one hundred and ninety-eight million dollars. If to this is added the cost of sanitation and civil government, and the amount originally paid the French company and the Republic of Panama, the total cost will approximate three hundred and seventy-five million dollars; while the cost of a sea-level canal, from estimates made at the present time, in view of the knowledge gained from construction work, would have been in excess of five hundred and sixty million dollars.

The canal when completed will be approximately 42 miles in length, the lock chambers will be 110 feet in width by 1000 feet in length. At no place in the entire canal will vessels have any difficulty in passing under headway. Even in the Culebra cut the width will be 300 feet. The narrowest channel outside of the cut will be 500 feet for a distance of about four miles, 800 feet for a distance of about four miles, 1000 feet for 15 miles, with a broad expanse of lake for the distance of 23 miles, and in this section practically no limit to speed need be enforced.

During the past year some thirty-five million cubic yards of excavation were made, some two million less than during the previous year; this falling-off was due to the fact that the field of operation is gradually being narrowed by the completion of work in certain sections. The latest officially revised figures in regard to excavation are approximately:

Total French useful excavation..........	30,000,000	cubic yards
Total American excavation.............	95,000,000	" "
Future excavation......................	80,000,000	" "
Approximate total excavation...........	205,000,000	" "

From this tabulation, it will be seen that the French excavations amount to about 14.6 per cent. of the total, the American excavations already performed about 46.4 per cent., and that 39 per cent. still remains to be done.

Outside of the magnitude of the constructive engineering, the most striking feature in connection with the construction of the canal has been the admirable sanitary conditions maintained throughout the canal zone, which converted this generally conceded pestilential district into one practically free from all usual tropical diseases. Perhaps nothing has contributed more largely to the apparent American success in prosecuting the work than this attention to the sanitary conditions, while the French failure may be largely attributed to a disregard of proper sanitation. It is interesting to note that in addition to looking after the sanitary welfare of the entire community, the Government carries on a most excellent subsistence department, polices the zone, administers justice, and looks after the recreation of the employees by providing club-houses equipped with billiard and pool tables, bowling alleys, reading-rooms, libraries, and assembly-rooms, all of which are evidently considered necessary to the healthful development of the proper "esprit de corps."

Fellow-members: In retiring from this office with which you have honored me, I wish to thank you for the cordial support you have given the administration, and the fraternal feeling that has always been extended to me personally. I bespeak for the coming officers an exhibition of the same loyalty, in which, I assure you, I shall join most heartily.

PAPER No. 1082.

DIAMOND MINING.*

HENRY LEFFMANN.
(Active Member.)

Read, December 4, 1909.

THE diamond owes its importance principally to its rarity and beauty, but it must not be overlooked that by far the greater number of the diamonds obtained are unfit for ornament. These find, however, extensive use as cutting and abrading materials, the diamond in all its varieties being the hardest natural substance known.

It does not appear that the ancient nations clearly distinguished the diamond from other hard and brilliant minerals, such as quartz, zircon, and garnet, but its nature and value were recognized during the middle ages. There is no positive evidence that the stone has ever been found in its *matrix;* that is, in the material in which, or from which, it was formed. It is not a characteristic product of any geologic age, or of any kind of rocks. For many centuries it was obtained almost entirely from river sands by simple methods of washing and sorting. A few localities furnished the bulk of the supply, the occasional finding of a stone here and there being only of passing interest, and serving often to raise hopes never realized. Of this type is the diamond found a number of years ago near Richmond, Va. A few diamonds have been found in the North Carolina Appalachians, so well known for their rare minerals. India was an important source of diamonds for Europe before the discovery of America. Golconda, a market town at which valuable materials were collected and sold, has become associated with the idea of wealth, but no diamond mines existed there. Prior to 1870 the Brazilian province, Minas Geraes (general mines), was an important source, the stones being obtained from river gravels. Many fine stones have come from this region and a few others of similar type. These yields are often called "old mine stones."

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* I desire to acknowledge my indebtedness to *The Diamond Mines of South Africa,* by Gardner F. Williams, General Manager De Beers Consolidated Mines, Ltd.

In 1867 a diamond was accidentally discovered in a South African village, on the banks of the Orange River. It weighed 23.5 karats (about 75 grains). In spite of much search, some months elapsed before more were found, but it was soon evident that an important supply could be obtained from the sands of the Orange and Vaal Rivers, and the usual "rush" began. Mining in these localities was industriously carried on. After some years of this method a diamond-bearing deposit of an entirely different character was found. The fact that garnets were generally found with diamonds in the river-beds led a local prospector to open up the soil of a farm in the Orange Free State in places in which he had noted the frequent occurrence of garnets. His ingenuity was soon rewarded by the discovery of a limited area yielding the precious minerals.

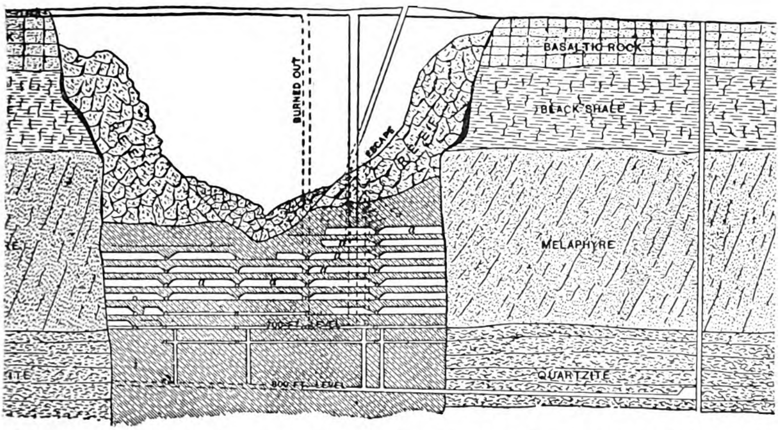
The conditions in this new mine were wholly different from those that had been anywhere else encountered in such mining. The locality was not alluvial, but a comparatively firm mixture of minerals, more or less igneous in their origin, filling a deep crater. The discovery was followed by others of the same type, and the world's supply of diamonds is now very largely derived from these South African deposits, termed "dry mines," to distinguish them from the alluvial localities. The craters are locally termed "pipes." They are of limited area (from ½ acre to several acres) and of unknown depth. One of them is now being worked at a depth of over 2000 feet.

The new feature, of course, gave rise to a new "rush." Owners of craters sold claims of a few square feet in area, and the exploiters began to dig, sieve, and wash the earth within the limits of their claims. Much confusion arose. Some, working faster than others, made narrow and deep excavations, causing collapse of neighboring banks. The area soon became so irregular that access to some claims became impossible. Legal interference was invoked for the purpose of maintaining roadways across the crater area, but it was only partially successful. The conditions were becoming intolerable, but finally the usual business methods of the present age were put in operation. Capitalists and promoters got control of many claims; finally a few choice spirits had all the important areas in their grasp, and at present the diamond-mining of South Africa is in the control of the De Beers Consolidated Mines, Limited, the names of Barney Barnato (actually Barney Isaacs) and Cecil Rhodes being especially prominent in the work of organization. Some mines are not directly

and other difficulties arose. Deep mining is now carried on by sinking shafts in the rock adjoining the crater and driving lateral galleries.

The blue ground taken from the deep levels is too hard to work, and crushing is, of course, out of the question, as valuable stones might be broken. It is necessary to "weather" the material; that is, allow it to be exposed to the air until it softens. This takes about a year, and hence large areas called "mine floors" are provided for the accumulated material. These are several square miles in area. They must, of course, be guarded. The crude rock is usually brought up in cars holding 1600 pounds. Some years ago the De Beers Company in its annual report gave the following figures:

Mined ....5,128,000 loads (about 4,000,000 short tons)
Yield..........2,210,314 karats of diamond (a little over ½ ton)

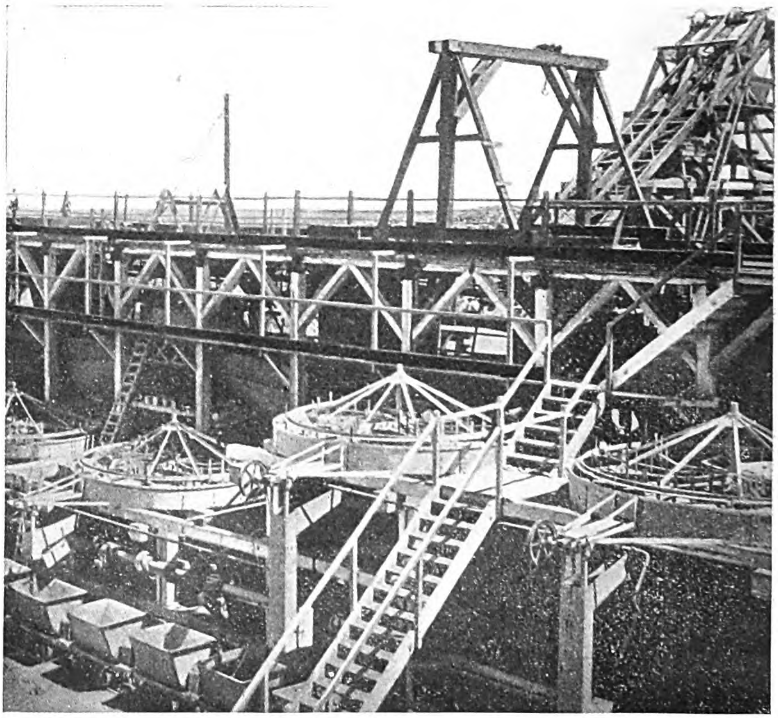


SCHEMATIC SECTION OF DIAMOND MINE AND ADJACENT ROCK (WILLIAMS)

A karat is 3.168 grains. The money value of the above was $24,000,000, so that the rough stones yield about $10.50 per karat to the mining company. The figure is probably slightly higher now. Of course, this is an average. Much of the material is far below the average value; some is very much above.

After the blue ground is weathered, it is broken up by plowing or by steam-roller, and then washed. The washing machinery is very elaborate. The illustration on page 100 shows one of these installations. By this means all the loose earth is removed, leaving the crystalline minerals, especially quartz, garnet, and zircons, mixed

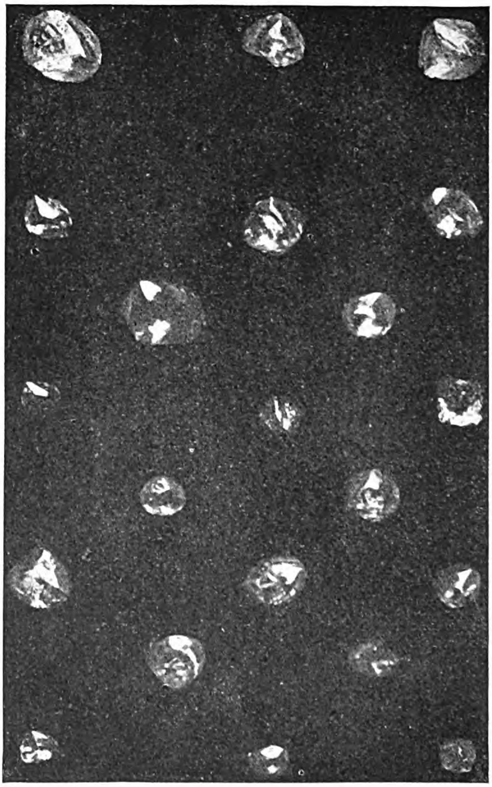
with the diamonds. It was formerly the custom to sort this by hand, but it was found that the diamond has a peculiar affinity for greasy surfaces, and a machine was invented called a "greaser," in which is arranged a succession of greasy cloths over which runs a stream of water carrying the mixed minerals. The diamonds stick to the cloth; the other minerals pass on. The sorting as to quality has to be done by experts.



WASHING MACHINES (WILLIAMS)

The theft of diamonds is easy, and the prevention of this has been one of the chief difficulties in the modern operation of the mines. The men who make a practice of buying stolen diamonds are known as I. D. B. (illicit diamond buyer). At present, the mining company holds all its ordinary workmen to a term of service, and keeps them within a limited area, called a "compound," in which are provided shelter, exercise grounds, swimming-pools, and other conveniences.

The finest diamonds have a slightly bluish cast, are perfectly clear and flawless, and their value, of course, depends in increasing proportion on their size. A diamond of three karats, of a certain quality, is worth much more than three times that of a diamond of one karat of the same quality. The karat, which is the standard weight, is 3.168 grains.



Collection of Diamonds Swallowed at One Time by a Workman. Weight 348 K. (1102 Grains); Value About $5300. All Recovered in Four Days (Williams) (½ Natural Size.)

Inferior diamonds grade all the way from those slightly off color to dirty, and even black or brownish stones. Uniform black diamonds are rare. The most inferior material is used for cutting and drilling purposes. Diamonds bear heat very well up to a certain point. They may then be very materially altered in appearance,

and at very high temperatures will take fire, burning simply with a glow, and produce, in a free air-supply, carbon dioxid. This determines the composition of the diamond as being carbon. Sometimes they contain enclosures of carbon dioxid under great pressure, and explode when even gently heated. True diamonds have been produced artificially, but only so minute as to be of no more than scientific interest.

No theory of the formation of natural diamonds has yet been offered which meets with general acceptance by geologists and mineralogists.

PAPER No. 1083.

DESTRUCTIVE ACTION OF MOTOR TRAFFIC ON ROAD SURFACES AND METHODS OF CONSTRUCTION TO PREVENT IT.

W. H. FULWEILER.
(Active Member.)

Read January 4, 1910.

Present type of broken stone road: Without going into the theory of the broken stone road of the present day, it may be said that the following are its essential features:

A well-graded and compacted sub-base that is so located and drained that it will always remain free from water.

A foundation composed of either compacted broken stones less than 3 inches in diameter, or else a rough pavement made of fairly broad stones set on edge and firmly wedged into place by spalls.

An upper course of smaller stones varying from 1½ inches to dust, the upper surface of which is so compacted by rolling and flushing that all its interstices are filled by decreasingly smaller stone particles. This fine stone dust exercises a mechanical, and probably also a chemical, bonding action on the larger pieces of stone, and results in a compact impervious layer that protects the body of the road from excessive moisture and resists the impact and wear of the traffic.

The theory of this form of construction requires that the abrasive action of the steel tires and horses' shoes shall grind off a sufficient supply of the fine cementing rock dust to replace that removed by the erosive action of the wind and rain and the impact of the traffic.

It is this factor of constant supply of fine material that occasionally causes the failure of a road when constructed of extremely hard stone and only subjected to rather light traffic, and in part explains the failure where the bulk of the traffic is rubber-tired vehicles which do not provide a supply of this material so essential to the proper condition of the road.

The action of motor traffic: With horse-drawn traffic, the wheels serve only as rolling supports for the load, while with the self-pro-

pelled vehicle they must, in addition, serve to transmit the torque of the motor to the road. This results in a radical change in the action of the tires on the road surface in addition to the change in their physical character.

There is, in addition to the vertical force due to the load, a horizontal force due to the motor, which tends to shear the surface of the road over the area of tire contact.

Considerable attention has been given to the varying value of this force, and it may be expressed as the sum of six terms:

1. A function of the weight of the machine, the friction on a driving-wheel, and the condition of the road surface.
2. The weight of the machine and the acceleration at any instant.
3. The air resistance, which involves the cross-section of the machine and the speed.
4. The weight of the machine and the grade.
5. The weight of the machine and the depth of momentary depressions in the road surface.
6. The weight of the machine, the speed, and the radius of the curves rounded.

The maximum value is, of course, attained when the tires begin to slip on the surface, and is equal to the weight on a driving-wheel multiplied by the coefficient of friction.

That this maximum value is frequently attained is proved by experiments, which show that the driving-wheels of a motor car constantly travel farther than the front wheels; when this occurs, as it constantly does, the rear tires, whose soft and generally slightly roughened surfaces are charged with minute particles of the rock dust from the road, act like a regular grindstone on the wearing surface.

The flexible nature of the rubber surface gives it a grip on the finer stone particles, so that the horizontal shearing force tends to sweep them from the surface voids, dropping them a few inches in the rear, where they are distributed over the road and adjoining property by the air-currents set up by rapid movement of the car.

There are a number of other actions which no doubt contribute to this result; such as the suction effect produced in the rapid passage of the soft tire over the road, the longitudinal stretching of that portion of the tire surface in contact with the road due to the rapidly changing value of the tangential force during the time that any point of the tire is in contact with the road, and the change in posi-

tion, in a transverse direction, of any point of the tire (except along the mechanical center line) as the cross-section of the tire is flattened at the area of contact.

The relative importance of these different factors is still the subject of considerable discussion, and it is possible that under different circumstances any one of these may assume a relatively greater importance; yet it is believed that in general the principal factor is the horizontal shearing force impressed on the road surface due to the torque of the motor.

The effect of these forces on the road surface: The summation of these forces results in what has been very aptly termed a scrubbing action of the tires on the surface.

Owing to this action, as previously explained, the fine stone dust, upon which the road depends for its stability, is drawn from the surface and dissipated. The larger and sand-like particles, which also play an important part in the interlocking of the larger stone particles composing the wearing surface, are then swept out of the interstices and the whole surface loses its stability, disintegrates, and is rapidly picked out and thrown into the gutters.

The infiltration of excessive moisture, carrying with it the surface detritus, serves to hasten the disintegration. As this wearing surface is stripped from the road, increasingly larger sizes of the stone are exposed to the horizontal shearing force and are easily displaced. The body of the road is less dense and compact as its depth below the surface increases, since the action of the roller and the flushing during construction are less efficient.

On long level stretches the destructive action is not so apparent unless high speeds are developed; it is at its maximum on curves and at the foot and on the ascending side of inclines where an abnormal torque is exerted to enable the machine to "rush" the hill, and on either side of roads where a number of machines must habitually stop and start quickly. It seems to require the passage of about forty motor cars per day, at speeds above 20 to 25 miles per hour, for destructive action to become apparent.

The possible effect of motor traffic on broken stone roads was discussed as early as 1901, but it was not generally apparent until about 1904. So rapidly has the use of motor vehicles increased since then, that to-day the destructive effect of motor traffic has become one of the most important questions before all engineers who have to do with road maintenance.

The extent of this action and its remedy: This destructive action may proceed so rapidly that a surface is entirely removed for a depth of two to four inches within a year or two, when the normal rate of wear would not be over a quarter of an inch. On curves it is frequently necessary with heavy motor traffic to entirely resurface the road every year, and to patch numerous ruts at more frequent intervals.

The remedy for this condition, if the present type of broken stone road construction is to be retained, is obviously to first retain the cementing rock dust in its proper place. This, however, is not sufficient, as the force exerted by the scrubbing action of the tires is greater than the bonding action which would be developed even

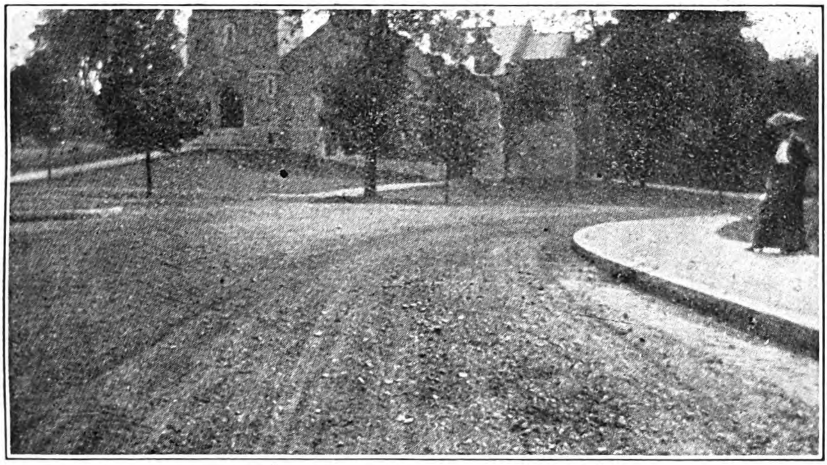


FIG. 1.—Raveling due to Motor Traffic.

under the most favorable conditions. It is, therefore, necessary to introduce some agent as a binder into the road surface that will develop sufficient strength to resist the shear of motor traffic and thus retain the stone particles composing the wearing surface in their proper positions.

Surface treatments have usually failed under heavy motor traffic: It has been well understood that a broken stone road requires a certain amount of moisture in the upper layers in order that the bonding value of the rock dust may be fully developed. It was thought that with increased care and attention to sprinkling with water the road might be kept up to its maximum efficiency, and thus

very unstable, as it is dependent upon very slight changes in the moisture content.

Surface coatings of oils and tars were then tried. These materials were applied either directly on the road, or as emulsions with water to facilitate their application and absorption in the road.

These surface treatments have undoubtedly been of considerable benefit under certain circumstances, both as allaying the dust nuisance and in preserving to some extent the continuity of the surface.

It must be remembered that when such materials as oil or tar are applied they usually destroy, to a very considerable extent, the natural cementing or compacting quality of the rock dust. This cementing quality must be replaced by the binder in the oils, so that their value is dependent upon the amount and strength of the binder which they actually bring into active action in the surface. In some of the preparations that have been tried this resultant binder is practically worthless, because the maker fails to realize what is required of a road binder.

The use of a larger quantity of a fairly heavy tar or oil, followed by an application of fine crushed stone or sand, came as a development of the purely surface treatments. In this method the finer dust and stone particles are removed, exposing the ¾-inch and larger stone. The binder is then applied hot, and thorough contact with the surface insured either by brooming or spraying it under pressure. The stone, screenings, or sand is then spread evenly and the road rolled.

The surface dressing absorbs the surplus binder that is not taken up by the road, and on rolling forms a new surface, of thoroughly bound particles, that is waterproof and will resist ordinary motor traffic. The thickness of this layer varies from ¼ to ¾ inch, according to circumstances, and lasts from one to two years, depending upon the materials, traffic, and the skill in application.

This form of treatment has been extensively used in England. The statistics collected by the Road Improvement Association for 1908 showed that 1630 miles of equivalent 21-foot road were treated as follows:

With tar macadam and similar processes...	52 miles =	3.2%
With penetration and similar processes.....	44 miles =	2.7%
With surface treatment....................	1290 miles =	79.1%
With emulsions, calcium chloride, etc......	244 miles =	15.0%

The treatment is fairly cheap and easy of application, particularly

when mechanical means are used for sweeping the surface and applying the binder, and serves a very useful and important purpose in preserving roads that are subjected to only moderate traffic. Under heavy mixed traffic it fails, owing to the small depth of protective layer that is formed. This is unavoidable on account of the small sizes of stone that must necessarily be employed and the nature of the binder that such a system requires.

In general, all surface treatments fail from the lack of true binder and the thin surface film that is formed.

Present ideas as to the proper remedy: The failure of the surface treatments under heavy motor traffic, particularly on curves and at other points where the maximum value of the shearing force is frequently developed, together with the realization of the many limitations as to the quality of the binder and size of stone that had to be employed, led to further experiments to develop the idea that was brought out at the First International Road Congress: viz., that for heavy motor traffic the binder should be incorporated in at least 2 inches of the upper surface of the road.

The methods thus developed may be divided into three classes:

1. Where the binder is poured in from the surface, thus saturating a prepared top coating of stone.

2. Where the binder is first mixed with the surface stone and rolled into place.

3. Where the surfacing is prepared at central points in large quantities, and delivered to the roadside ready to be spread and rolled into place.

The penetration method: The first of these has been termed the penetration method. It consists in first preparing a well compacted top layer of stone smaller than 1½ inches, and filling the voids by pouring in the hot fluid binder.

In order that successful results may be obtained, a number of points must be observed.

In resurfacing an existing road, the old surface should be picked up with a scarifier, brought to the proper cross-section, and rolled. With new work, the foundation or lower course of the larger stone should be filled or sealed with some form of binder, either screening, sand, gravel or a mixture of these with loam. This is used to prevent the bituminous binder for the upper course running down into the foundation, where it would be of no use.

The stone for the upper layer is then spread to a depth that will give a finished depth of at least 2inches, and, better, 2½ inches.

This stone should, if possible, be graded slightly, that is, sizes should be from 1½ inches to ¾ inch. As the rolling is started, a small quantity of ¾-inch stone should be spread evenly ahead of the roller so that the whole layer may be thoroughly keyed up from the bottom, and the larger surface voids filled with ¾-inch stone. The quantity of ¾-inch stone used will run from 15 to 20 per cent. The rolling should continue until a firm, compact surface is obtained, free from waves, but should not be carried on after the edges of the larger stones (particularly with limestone) begin to round off. When this layer is properly rolled and thoroughly dry, the binder may be applied.

The uniform distribution of the binder and its temperature are quite as important as the preparation of the stone. In order that the binder shall properly coat all the stone and fill the smaller voids, thus giving a well-bound aggregate, it is very important that its consistency at the time of its application should bear a proper relation to the temperature of the stone.

If the binder is applied too cool, it chills on the surface and does not flow freely into the smaller voids, and thus coat the lower stone, and an excess will have to be used to even cover the surface.

If, on the other hand, it is too fluid, it runs directly through the upper course of stone without leaving a coating of the proper thickness, and collects in pools on the binder of the lower course, where it rises in places to the surface, fôrming soft spots in summer. There is also a tendency to apply an insufficient quantity, owing to the ease with which it flows over the surface stone.

The subconscious effect of the fluidity on the man who is applying the compound is very interesting, as the amount applied per square yard can be varied quite widely by changing the temperature without the laborer being aware of it.

That the compound should be applied uniformly is, of course, self-evident, and there are a number of schemes for doing this. The earliest was the use of ordinary coal-scuttles, the flat lip delivering a fairly even ribbon of binder on the road. Garden sprinklers with either a specially punched rose or a thin, vertical, fan-shaped nozzle have been used on small stretches quite successfully. Light skeleton frames enclosing one or two square yards of surface have been used as a guide to determine the proper amount to be applied.

On larger areas iron tank wagons are usually employed to heat the binder, and it is applied through a hose with a flat, fan-shaped nozzle. This method has been improved recently by applying pressure from

small cylinders of highly compressed air and the use of a spraying nozzle.

Several forms of mechanical distributing devices have been recently developed, which seem to do very efficient work. Their claim for recognition so far has been based more on rapidity than on uniformity of result, for the reason that the stone surface is not entirely uniform, and a skilful workman can apply just the correct amount at each point; while, on the other hand, the machine moves so rapidly that it is more difficult to quickly change its rate of delivery to suit varying conditions.

It will generally be found that the rate of progress with this method

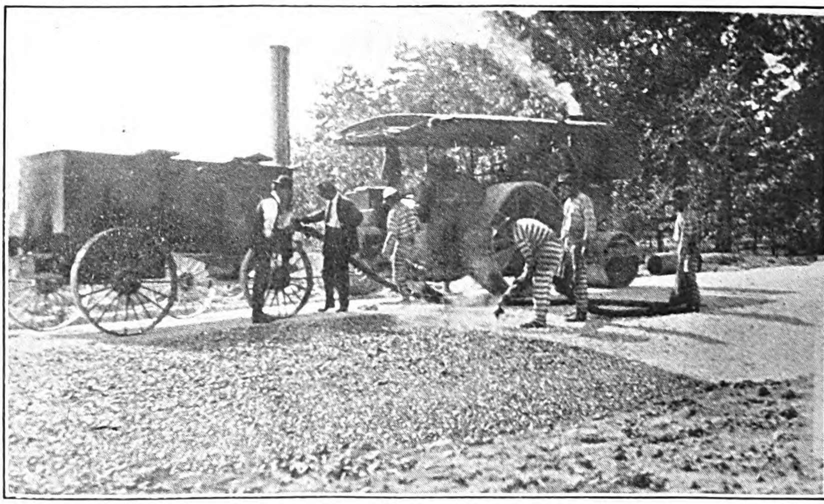


Fig. 3.—Spraying Tar; Penetration Method.

is dependent more upon the facilities for heating the binder to the proper temperature and delivering it to the work than upon the method of applying it. The time saved by rapid spraying is frequently lost by waiting for hot material, or in driving back and forth from the tank car or other source of supply, as an iron tank wagon holding four or five hundred gallons is no mean haul. The great weight of a full tank wagon, even with wide tires, frequently causes ruts in the stone that are very difficult to roll out, and sometimes show in the finished surface.

The quantity of binder per unit of area varies quite widely with

Under favorable conditions and proper workmanship this method yields very good results, but it is exceedingly important that every little detail be carefully watched.

Improper preparation of the lower or foundation course, lack of care in securing a dense and compact upper course, presence of excessive dust or moisture in the upper course, cold damp weather, uneven distribution or the use of a binder not adapted to the conditions, and careless application of the flush coat, are all points which if overlooked or neglected will cause unsatisfactory results.

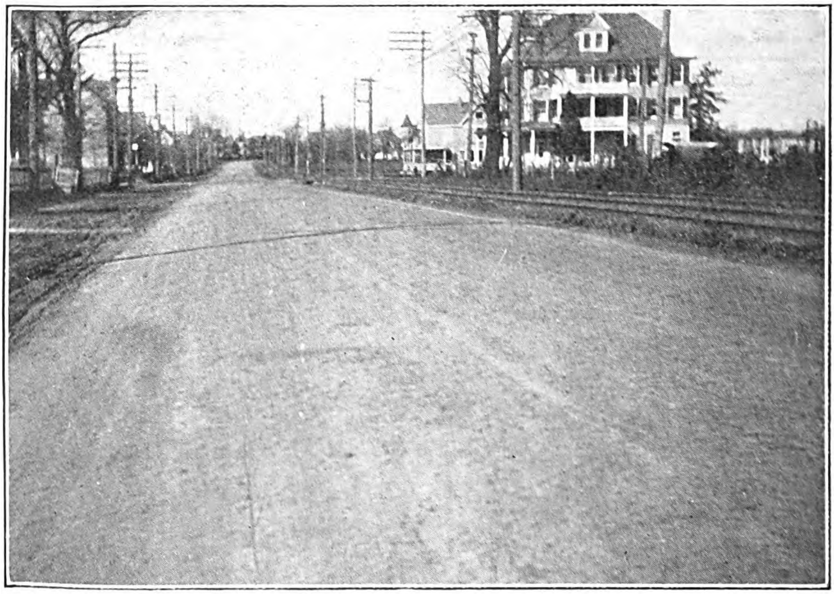


FIG. 5.—Finished Surface; Penetration System.

The fact that no special appliances beyond the heating tank are required, and that the labor cost is low, brings this method within reach of the ordinary road contractor.

Methods of using non-bituminous binders: There are two non-bituminous binders that are used in a manner somewhat similar to the penetration method. They are "Glutrin" and "Rocmac."

Glutrin is prepared from the waste liquor from the sulphite process of making wood pulp. It is a dark brown liquid of about 30° Beaumè, and is said to be a complex organic salt of calcium.

This is diluted with water and sprinkled on the road from an ordinary sprinkling cart, so that it is extremely easy of application. On drying, it yields a very hard and compact surface that is quite free from dust, and that seems to resist ordinary traffic very well. The length of time that it remains effective depends somewhat on the rainfall (as it is soluble in water) and on the traffic, but on roads not subjected to heavy motor traffic, it will apparently last through a season.

The other material is known as "Rocmac," and is said to be a compound having sodium silicate as a base, and sugar, mixed with powdered calcium carbonate, a pure form of limestone.

This mixture is applied to the depth of about an inch over the old surface, and the stone for the top course spread over it. The surface is rolled until the binder has filled the voids and rises on the surface. It is then swept evenly over the road, and a thin coating of limestone dust is sprinkled over it to protect it while setting up, which requires from two to six days. The compound combines chemically with the limestone, forming a cement, which serves to bind the wearing surface into a compact mass.

The mixing method: In order to secure more complete control over the distribution of the binder, and a more compact stone mixture in the wearing surface, considerable attention has been devoted to the mixing method of construction.

This is but a development of the earlier form of tar macadam that has been used with varying degrees of success during the past fifty years. With the increase in our knowledge of the properties of binders and their preparation, and the proper working conditions for their use, which has resulted from the experimental work done both here and abroad during the past ten years, this form of construction has been brought very much to the fore. Already two State road authorities, Rhode Island and New Jersey, have decided to use it exclusively.

With this method the foundation course need not be filled, as in the penetration method, but it should be thoroughly compacted. In resurfacing old work after the surface has been brought to crown, some form of bond should be provided between the old and new work. This is best secured by rolling in an even one-stone layer of 2½-inch stone.

A light sprinkling of tar oil is of considerable advantage before spreading the top course, as it penetrates the dust on the surface of

the binding stone and secures a better adhesion of the tarred aggregate.

The important points in the preparation of the wearing surface are the grading and quality of the stone, the quantity and quality of the binder, and the method of combining them.

In general, the better qualities of trap and granite still retain their advantages when used in this method, but many rocks that would weather badly or be too brittle in the ordinary water-bound macadam, may prove very useful when incorporated with a bituminous binder, as the stone is protected from the atmospheric agencies to a considerable extent, is held more firmly in position, and is subjected less to internal attrition.

In the earlier form of tar macadam but little attention was paid to securing a compact mixture. Several courses of uniform sizes of stone were used, the finer at the surface. As the method was developed, the necessity for more careful and uniform grading of the mixture became apparent, and it has been found more desirable to have a reasonably large proportion of the larger size stone in the surface, with sufficient smaller particles to properly fill the voids and interlock and support the larger sizes.

The stone mixtures in use vary quite widely from the more or less complicated grading used in the Warren Bros. "Bitulithic" (where an attempt is made to reduce the voids in the stone mixture to a minimum by careful grading and the use of "dust" or "filler") to the rather more open mixture which is used by the Rhode Island Commissioners, and contains nothing smaller than ½-inch stone.

It is possible that the mixture with the minimum voids secured by the use of "filler" may be theoretically stronger, yet very satisfactory results may be secured with mixtures whose voids will run very much higher. The more open mixtures give very much less trouble in mixing, as the finer dust and stone particles have a tendency to collect the binder and roll into balls, so that the larger stone size does not secure a proper proportion of the binder. This is not so noticeable when using heated stone as when the stone is mixed cold. Various schemes have been proposed to obviate this difficulty, one being to mix the larger stone with a slight excess of binder, and then add the finer stone particles and dust.

Owing to the fact that the whole process is under complete control, the binder may be considerably heavier and stronger than that used in the penetration system. It is thus possible to use a semifluid

binder, if desired, and to secure the maximum strength possible in the finished surface. Due regard must be paid to the behavior of the binder when exposed to low temperatures, as it is important that it should always remain elastic and show no tendency to become brittle and thus powder under the traffic. When the stone has been properly graded, the binder may become quite soft under summer temperatures without the surface yielding to any noticeable extent.

The quantity of binder varies with the grading of the stone. In very dense stone mixtures, owing to the larger percentage of the smaller sizes and the greater surface they expose per unit of weight, an additional amount of binder would be required, but to some extent

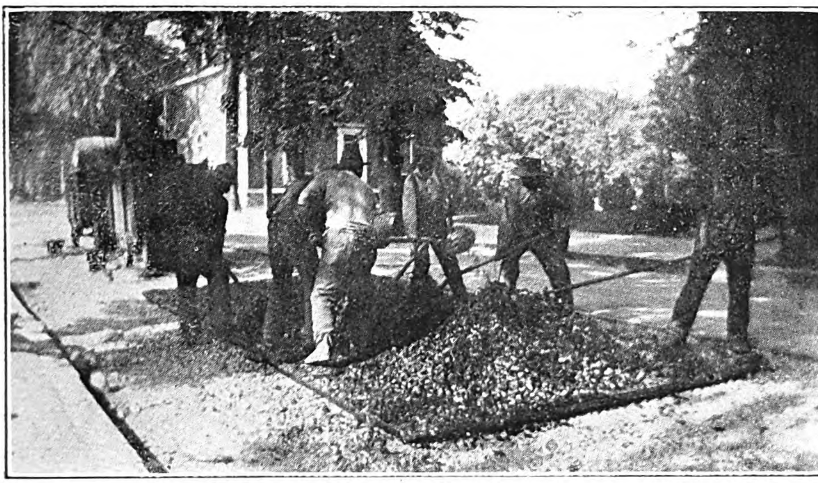


Fig. 6.—Mixing the Macadam—Hand.

this is reduced by the smaller percentage of voids in these mixtures that have to be filled.

The percentage by weight will run from 5 to 6 per cent. to 8 or 10 per cent., the latter being used in mixtures containing a large proportion of fine screenings, sand, and dust. The average percentage for the usual mixture is about 6, so that a cubic yard of stone would require about 170 lbs. of binder.

It is exceedingly important that the stone should be quite dry in order that it may be thoroughly coated with the binder, but in summer weather it is not essential that it should be heated unless there is a considerable percentage of fine stone or dust in the mixture.

While heating the stone is both troublesome and expensive, yet the mass may be much more thoroughly and easily mixed and handled, trouble from damp stone is avoided, and better results may in general be expected when this is done. In cold weather it is, of course, quite essential.

Various forms of temporary heaters have been used, but the best results seem to follow the use of broad and almost flat iron pans about 8 feet long by 4 feet 6 inches wide and 18 inches high, stiffened with angle irons and provided with a stack at one end. Several forms

FIG. 7.—Mixing Tarred Macadam—Machine.

of mechanical dryers are in the market which give very good results, but in general their cost is high, and unless a large amount of work is in progress they are hardly necessary.

The stone should be heated until it is thoroughly dry, about 200° to 225° F. being sufficient, while the binder should be heated to some point dependent upon its nature that will render it quite fluid, usually from 250° to 300° being sufficient.

The mixing may be done on movable wooden platforms, as in concrete work, or in some form of mechanical mixer. The blade type

of trough mixer seems to give the best results, as its action is more nearly like that of the usual form of mixer used in the asphalt plants.

Usually two turns on the mixing board by hand will give a good coating. It is better to add half of the binder to the stone; turn once, then add the remainder and turn again.

The mixed aggregate should be placed on the road as soon as possible, as it may then be handled with greater ease and there is less tendency for the binder to collect in the lower layers. If it must be hauled to any distance from the mixer, the pile as dumped from the cart should be carefully turned over before being placed, as there is a tendency for the stone to segregate in sizes and the binder to collect at the bottom. Bottom dump carts are particularly likely to leave the mixture in this condition.

In leveling the aggregate care should be taken not to bring an excess of the larger sizes of the stone to the top, as it is almost impossible to get them down again, thus leaving the surface rough and full of large voids.

As soon as the surface has cooled so that the roller may be used, a light rolling is given to insure a smooth surface. After several hours, when the body has cooled so that it will not slip, a thorough rolling is given until the surface is as compact and smooth as possible. At least a 10-ton roller should be used for the final finish, and a 15-ton would be preferable.

A flush coat of very hot binder is then applied, as in the penetration method, to seal off the surface voids. About 0.5 to 0.7 gallon per square yard is required. This is followed by a light coat of hard, clean stone screenings and a final rolling. The screenings give a finish and tooth to the surface, which would otherwise tend to be "slick," especially in frosty weather.

The rate of progress by this method is necessarily much slower than with the penetration method, and the labor cost correspondingly much higher. Six mixers and two tar men, if kept supplied with materials, should mix and lay about 300 square yards of 2½-inch top dressing per day. This rate of progress will require favorable conditions. With machine mixing and proper facilities this should be doubled.

Another form of construction is that known as the "Petrolithic" or "Imperial." With this method the old road surface is plowed up, harrowed, and thoroughly pulverized, and a heavy grade of asphaltic base oil is applied and thoroughly worked into the soil. The surface

is then compacted by means of a rolling tamper. A layer of crushed stone is then put on the road and another coating of oil is supplied. A rolling tamper is then put on again until the surface is compacted, and final smoothing is generally given with an ordinary steam-roller.

This construction seems to have given satisfaction in some of the western States and in California, but whether it is due to our peculiar climatic conditions, or to an incorrect principle in the process, it has not been very successful in our eastern States.

Prepared top surfacing: In order to obviate the difficulties in

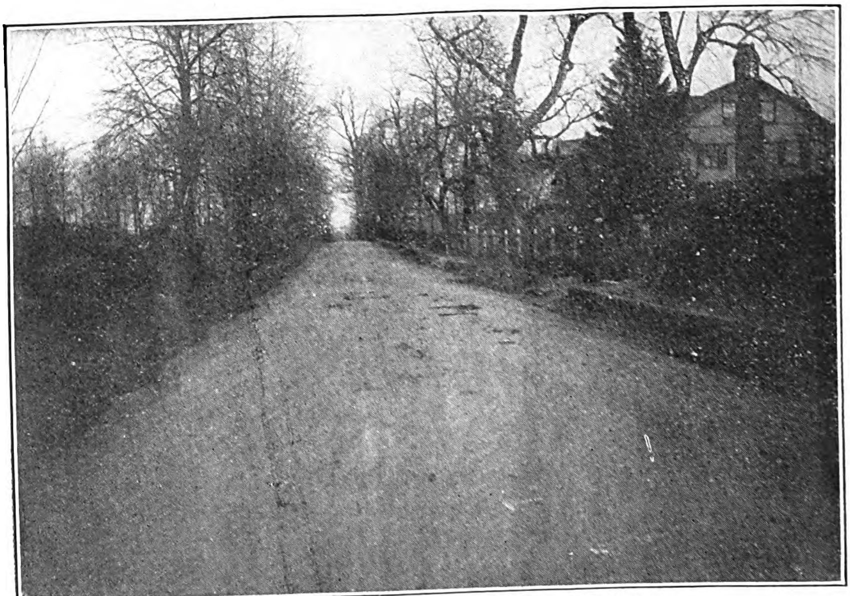


FIG. 8.—Finished Surface; Mixing Method.

securing a properly graded and uniformly mixed aggregate for this form of construction, and the other attendant difficulties of preparing a uniform product at the roadside, a number of preparations have been brought out which are ready to spread on the road and roll into place.

Probably the first was "Tarmac." This is an English preparation made of graded slag, which is mixed hot with coal-tar and seasoned for some time before being used. "Tarfaat" is a similar mixture prepared of smaller sizes for surfacing only. "Tarlithic" resembles

"Tarmac," but the aggregate is made of stone. "Quarrite" is tarred stone of uniform size. These are delivered in the different sizes and mixed on the road, the argument being that with stone of uniform size there are relatively fewer points of contact than in the graded mixtures, so that the aggregate can be more easily handled and a tougher binder employed.

In this country "Amiesite" has been used to some extent. This is a graded stone mixture and an asphaltic base oil, treated by a patented process with lime and sand. This material is supplied in two sizes, a larger size for the body of the road and a finer size for the surface. It has given very promising results. "Filbertine," an asphalt-stone mixture, is another preparation that has been recently put on the market.

The Wadsworth macadam is a prepared natural bituminous rock or sand. This material is spread on the 1½-inch stone and rolled into the interstices, thus compacting the whole layer and forming a smooth surface. At any distance from the mines the freight charges make it rather expensive, and it only works well under certain temperature conditions, and, like all natural products, the percentage of bitumen and the grading of the sand particles vary considerably.

The grading of the sand, moreover, is not very satisfactory, according to the present standards that have been evolved in the asphalt paving industry. It has given very satisfactory results, however, in some instances.

The principal labor cost in using these prepared materials is the handling from the car, as they have a tendency, especially in cold weather, to pack quite solidly, requiring both time and patience for their removal. Considerably more rolling is also required to compact them than in the other methods, as they yield quite slowly and must be rolled very hard to secure the best results.

The principal disadvantage so far in the use of these prepared materials is their high cost, which is due both to the high cost at the point of shipment and the necessity of paying freight on a long haul of the stone, which might otherwise be obtained locally.

Another point is the fact that, as in the penetration method, the quality of the binder must be sacrificed to some extent to enable the material to be handled and compacted for some time after its manufacture, and yet harden to such a point when in place that it shall acquire a proper strength to perform its function of resisting the action of the traffic.

When these points have been satisfactorily solved, the method seems to be an ideal one.

We may summarize the relative advantages and disadvantages of these methods as follows:

PENETRATION SYSTEM.

Its disadvantages are:

1. The care necessary to secure a properly prepared upper course of stone,
2. The difficulty in obtaining uniform distribution of the binder through the wearing surface,
3. The necessity for using an excess of binder,
4. That the quality of binder must be sacrificed to some extent to the requirement of the method,
5. And that in cold or damp weather this method cannot be successfully used.

Its advantages are:

1. Low labor cost.
2. Quickness and ease of application.
3. No expensive apparatus required.

MIXING METHOD.

The disadvantages are:

1. High labor cost.
2. Slowness of application and trouble required in mixing.
3. More apparatus required.

Its advantages are:

1. Complete control over the distribution of the binder and resulting uniformity of the mixture.
2. Ability to use a more suitable quality of binder, and to effect a considerable saving in the quantity required.

PREPARED SURFACING.

Its disadvantages are:

1. Very high first cost.
2. Trouble in handling during cool weather.
3. Quality of binder that must be employed.

Its advantages are:

1. Ease of application.
2. Uniformity of mixture.

The National Pressed Brick Manufacturers' Association has developed specifications for the construction of this type of road, and has done a great deal of educational work to promote its introduction.

Some of the claims made for this construction seem hardly to be realized, but in general it has given satisfactory results.

The high initial cost, dust collected from the side roads, and lack of resiliency are the chief disadvantages.

There seems, furthermore, considerable to be learned regarding cracking and spalling, and the effect of temperature changes. Their claim to permanency and freedom from repairs has still to be demonstrated.

The use of concrete in road construction has also been experimented with to some extent.

In all forms of non-elastic paving the question of temperature change is very important and not yet well understood. It has been the custom to place expansion joints transversely at intervals in the surface, and in some cases longitudinally, to care for these changes. The edges of the joints, thus formed have usually given a good deal of trouble by spalling off, and forming a deep groove. The idea of making the whole road a monolith is now being tried in several western towns, and the results will be of considerable interest.

Two methods have been used in laying the concrete. In one a 4-inch to 6-inch layer of rather lean concrete is laid as a foundation course and finished with from 1½ to 2½ inches of rich concrete. In the other, the body of the road is built in the usual manner for a broken stone road, and the upper 3 or 4 inches grouted with a rich cement grout while in place. This latter method results in a much lower labor cost, but, similar to the penetration method of using a bituminous binder, it is more difficult to secure the same solidity and uniformity than where the concrete is mixed before being placed.

The question of surface finish to secure proper footing in bad weather is also an open one.

A typical example of concrete construction is a road built during the past year at Detroit, Mich. The surface is 17 feet 6 inches wide and is composed of 4 inches of 1 : 2½ : 5 concrete in the lower layer, and 2½ inches of 1 : 2 : 3 concrete on the surface. Expansion joints were placed transversely every 25 feet.

An interesting experiment was made at Newton, Mass., where a broken stone road was surface grouted with cement and then given

a coating of a bituminous binder and screenings. This composite method of construction seems to give very satisfactory results, as any surface cracks in the concrete that might form are filled by the bituminous surfacing, which also supplies the footing and resiliency that are lacking in the ordinary form of construction.

The use of small cubical granite blocks laid over a sand cushion on a concrete or broken stone foundation has been tried abroad, principally in Germany, where it is said to have given very remarkable results, particularly as regards durability. The granite blocks are about 3½-inch cubes, and are made by automatic machinery from the waste pieces left in cutting the larger "Belgian" blocks.

When these blocks are laid in segments of circles, having chords 5 or 6 feet in length across the road surface, and grouted with a tar or pitch compound, the construction is known as "Durax." This form is said to be the ultimate solution of the problem for heavy motor and mixed traffic, being noiseless, dustless, and anti-skidding, but it has not been tried sufficiently to substantiate this claim. It would probably cost considerably more than either brick or cement.

Should this form of construction be adopted generally, it would be an interesting revival of the old Roman method of road building.

Conclusion: Looking at the problem broadly, the advent of the automobile with its destructive action at high speeds on the older form of broken stone roads has not been without its compensations. It has been the direct means of attracting a great deal of attention to the general condition of our whole road system. Our roads have needed this, and have deserved it for many years, and the present increasing interest in their construction and maintenance has been the means of proving in no uncertain manner that the first cost of improved forms of construction is more than outweighed by the decreased cost of maintenance, and it will yield valuable results to the States and counties that go into the question seriously, as nearly all of our States are doing or are about to do.

Methods of construction have been developed, imperfect as future work may show them to be, which if properly carried out will prove quite satisfactory under our present traffic conditions.

With more general use of the heavy motor truck on both urban and rural roads, that is already becoming a factor abroad, and the practical disappearance of heavy horse-drawn traffic, a new set of conditions will have to be met and overcome.

At the present time, however, the most general solution of the

problem lies in a surface composed of rather coarse stone, well graded into a fairly dense mixture with finer particles; the whole thoroughly incorporated and compacted with some stable, tough, and elastic binder.

DISCUSSION.

J. W. Hunter.—When I left Harrisburg to come to this meeting, it was not with the intention of having anything to say upon the subject of Mr. Fulweiler's paper; I came here to listen and to learn. The paper has been very interesting to me, and the work as outlined there is just the beginning, or an endeavor to get the information that we want in the method of building roads. It seems that the great thought now is to build a road that will stand the automobile traffic, forgetting for the moment that there are other means of conveyance and travel, and to build a road that is going to meet successfully all the requirements is something that we have not yet been able to accomplish. The road that will meet all the requirements of the automobile traffic is a road that is practically too hard and too rigid for the ordinary horse and wagon traffic.

The ordinary telford or macadam-telford road is—outside of the good earth road—the most desirable for ordinary horse travel, but it will not stand the automobile traffic unless the motorists will condescend to keep their speed down to say twenty miles an hour, at which speed but little injury would be done to the roads.

The Department has been making experiments with various methods of construction, and doing some work in that direction, but just what is best, we are not yet able to determine. Various conditions arise which make us think at times, when we believe we are just about to get something good, that we really know nothing about it, but we still have hopes of accomplishing something.

The various methods of construction described in the paper just read are to a great extent those we have used. The penetration method we have used a little, in applying a bituminous binder. For my own part I prefer the mixing method, and think we get better results from it, because every particle of stone is covered with the binding material. We have gotten the best results with 1½-inch stone, filling in with ⅛-inch to ¾-inch screenings, absolutely clear of dust. And I want to state right here that in trying any of these methods, the man making the experiment cannot be too careful in having the road perfectly clear of dust. If you take the general run of crusher and eliminate the dust, you will get very good results by mixing it with a bituminous binder. Another thing is to have the stone dry, as mentioned in the paper. It is almost impossible to make a bituminous material adhere to a stone that is full of moisture; in fact, it is money thrown away to attempt to make such a mixture and expect to get good results.

One of the difficulties we are up against is the fact of the bituminous binder not being uniform; that is something to which a great deal of attention will have to be paid, and an easy and quick method devised for testing bituminous binders.

In surface-treating of the oiled road, we have used the method of pouring the material on by hand and by sprinkling, and by putting on the screenings down to

⅛ inch in size, and after that has been thoroughly packed, applying a portion of screenings containing a considerable amount of dust.

In regard to concrete: We have tried the concrete road. We tried that once by reason of a cloudburst which tore off a section of our road, leaving the telford exposed, and to meet such a condition, should it occur again, we made a mixture of 1 : 3 : 5 concrete and applied it on top of the telford to the depth of 4 inches, rolling and tamping it in until the slush came on top, and then applying ¼-inch to ¾-inch rock screenings free from dust on top, tamping these until about half the stone was embedded in the slush, and finally covering the surface with a screening containing 5 per cent. of dust. On one portion of the road we put in expansion joints and in another section we put in none. The section in which no expansion joints were placed is to-day the better section of the two. We have since put in several sections of that kind of concrete road to overcome the washing by floods or high water.

I do not know that I have very much more to say in regard to this subject; it is largely a matter of experiment, and we are trying to learn. We have several sections of road put down in the way I have described, and we are waiting until the winter is over to ascertain how they have stood up.

We have used the Amiesite method, and so far have obtained good results with that mixture.

We have also used a preparation made by the Commonwealth Construction Company, a mixture which they invented and put down for the Department on a section of road near Harrisburg. On top they put an inch covering of sand and asphaltic binder, making practically an asphalt finished road. We cannot tell, however, until the spring, just what the winter's use of the road will show.

We tried the brick pavement in some sections. Our reason for trying it was because it was practically the cheapest material we could use in the section where it was laid. It has so far given good results. It makes a rigid paving and fit for heavy wagon and automobile traffic, but it is possible that the farmers and others who want to drive fast horses over it will eventually find fault with it.

I would like to ask Mr. Fulweiler, in regard to the brick road he showed, how was the brick retained in place? What sort of curbing was used?

Mr. Fulweiler.—There was a concrete curb on each side, and the bricks were laid on a sand cushion and grouted with cement.

Mr. Hunter.—We have used concrete curbing, but in nearly every case we have made it flush with the road. We have also used a gravel foundation and the sand cushion, and have obtained very good results from that method.

S. M. Swaab.—I would like to ask Mr. Hunter what kind of expansion joint is used in concrete road work?

Mr. Hunter.—It is made of tar-paper, ¼ to ½ inch thick, but even a one-eighth joint is entirely too wide, as at the joints the concrete chips off unless the concrete is covered with screenings at the joints; it is apt to be chipped off by the caulks on the horses' shoes.

Benj. Franklin.—I would like to ask Mr. Hunter if he thinks, if automobile traffic was regulated to a speed of twenty miles an hour, ordinary telford would be considered satisfactory?

Mr. Hunter.—An automobile running at that speed would not destroy the road. Of course, the injury from automobile traffic is more than from ordinary horse traffic. It is the heavy machines running at high speed that do the damage.

Mr. Franklin.—Could not that be bettered by the constant sprinkling of the road?

Mr. Hunter.—Yes, it could.

Mr. Franklin.—In other words, it would not be necessary to use the tar preparation continually?

Mr. Hunter.—No, not if the water can conveniently be had; there is no cheaper method of preserving the road.

Mr. Hunter.—That is a very important point, the cost of the bituminous binder. To my mind, if we can secure a bituminous binder in place at a cost not exceeding $1000 or $1200 a mile, it would be economy to use it, particularly where the road is subject to automobile traffic. The additional amount in the first cost will be more than offset by the repairs to the ordinary roads, and to my mind it is cheaper to apply the bituminous binder when putting down the top course rather than build a road, complete it as a macadam or telford-macadam road, and then apply the bituminous mixture by penetration or surface treatment. Penetration treatment would not last more than about three years. As a usual thing it takes a treatment every season for two years, missing the third year, then applying it again the fourth year, missing the fifth year, and then applying it again the sixth year, and so on. It is cheaper and gives better results, and a better wearing surface, to incorporate a bituminous binder with the top course of stone; it gives a more resilient road, and will probably make a more waterproof road, which is a very essential thing.

The State Highway Department is now building an experimental section of road on which we are dividing the method of construction to some extent; that is, we are putting a brick section alongside of the macadam section, laying bricks for the traffic going up the hill, which has considerable grade—I think the hill is something like a mile in length—and then on the counter hill the brick is put on the opposite side of the road, so that the traffic going up the hill would have the use of the brick, and the traffic going down the hill would use the macadam.

The ordinary road in the State of Pennsylvania is 33 feet wide, and when you come to take one-half of that for a roadway, a 16-foot strip, it is a difficult proposition to do just what you would like to do with it. Sometimes you cannot get more than 12, 14, or 15 feet. Generally the narrowness of the road will prevent putting down a macadam road on one side and leaving a dirt road on the other side. We are limited by the Act under which we build our roads, which says that we cannot construct a roadway less than 12 feet in width, so that we cannot very well follow that kind of construction.

Some of the old turnpikes were constructed with stone on one side and dirt on the other, and gave fairly good results, but since the turnpikes have been allowed to wear out, it makes a bad road. You cannot very well drain them unless you drain from the center to either side, and if you are going to drain a stone road on to the dirt section, you are going to have a bad road at all times.

J. O. Clarke.—Mr. Hunter called attention to a very important consideration when he stated that the requirements for horse traffic are entirely different from those for motor traffic. A smooth, rigid pavement is hard on horses, and we must hope that the investigations on the subject will result in the perfection of a road material that will be sufficiently tenacious to resist the wear of motor cars, sufficiently elastic and not too smooth for horse traffic, and cheap enough to save in maintenance charges the interest on the additional first cost.

The experience at Valley Forge Park may be of interest in connection with the discussion of the effect of motor cars at low speed on macadam roads. The commission in charge of that park has never succeeded in getting an appropriation for installing a water-supply, and the five miles of telford and macadam roads constructed there are dependent upon precipitation for moisture. The rate of speed is ten miles per hour. In the woods where the roads never become entirely dry the effect of the motor traffic is not serious except at sharp turns, but out in the open, and there are stretches of road that are entirely without shade from sunrise to sunset, the motor cars even at that low speed are doing a great deal of damage. Of course, a water-bound road should be sprinkled to give good results even under horse traffic, and at the time of the dedication of the Wayne statue, in the drought of June, 1908, one of the unshaded park roads was simply torn to pieces by the combined effect of the passage of a battery of artillery, some heavy omnibusses, and the motor cars.

As to the surface treatment of existing roads by tarvia, particularly the earlier tarvia products, it seems to me that this process is fundamentally wrong, because it puts a hard finish on a loose bottom, a bottom which disintegrates further by the action of the applied material in preventing the access of the moisture necessary for maintaining the bond. A telford or macadam road one or two years old is not fixed in the sense that a concrete base is fixed, and the life of a composition pavement depends very largely upon the character of the foundation. This is illustrated by so plastic a material as asphalt, which requires very frequent repairs on streets where the base is a macadam of broken cobble stones as compared with streets having a concrete foundation. My experience with tarvia is confined to some short stretches of road just outside of the city limits treated a few years ago. There is no question but that it has maintained the roads and prevented dust at a moderate first cost better than would have been the case if the roads had not been treated, but I have noticed that the tarvia gives way in small patches, leaving lens-shaped depressions about the size of a hand and about half an inch in depth. It seems to me that these patches will add very considerably to the cost of re-tarviating, as they should probably be picked out by hand, refilled with stone, and re-rolled before the next coat is applied, to make sure that they will not form pockets and catch too much tar. This matter has been called to my attention by the appearance of some other re-treated roads which still show the old depressions and ridges. I should like to know if the elimination of these defective places does not add very materially to the cost of re-treating, or if Mr. Fulweiler knows of a method by which they can be properly filled in without much additional expense.

Mr. Fulweiler.—I am afraid Mr. Clarke is laboring under some slight misunderstanding in regard to what a properly tar-treated road should be. One of its strongest points is its resiliency, and is intended to yield an elastic surface on the road, which makes it more pleasing to drive over than a road that has not been treated. Of course, a great deal depends upon the manner of its application, and the temperatures both of the road material and of the tar compound. If the tar compound is properly prepared, it should always retain its elasticity. If it hardens, of course, its life is gone and it rapidly disintegrates. In order to keep the material elastic and of the proper consistency throughout its life, great care should be bestowed upon the manner of its preparation. It is quite easy

to make a strong but brittle material, but what we require is one that will stay more or less like rubber at all times. Horses driven over a properly tar-treated road should make very little, if any, noise.

The point Mr. Hunter makes about a double road is interesting, and is being tried out practically in the middle west, where they are paving half the road with brick and leaving the other half a dirt road. As the brick is hard, the teamsters take the dirt road, leaving the brick road to the automobiles. In this connection, I presume you are familiar with the Road Bill now under discussion in England, where they propose to build an extra set of roads entirely for motor use, and in this way they will be able to meet the conditions of both kinds of traffic to the best advantage.

Referring to Mr. Clarke's question as to the cause of the tarred surface breaking out in spots, I would say that this is generally caused by dust in the road; that is, the men who were sent to clean the road did not do their work thoroughly. or else the men who were to brush the tar into the road did not put enough weight on their brushes. You cannot mix tar and dust. You have to get rid of as much dust on the surface as you can, and then bring the tar or oil into actual physical contact with the stone by means of the brush or broom. If the broom is merely dragged over the top of the stone, the tar is in many places held away from the stone by a surface film of dust, and thus an incomplete contact is secured. The action of the traffic soon destroys the film of tar, and in the spring the water soaks down through these bare spots, penetrating the stone and disintegrating the surface, so that you soon have quite a large hole resulting from the initial small spot where the surface film of dust had not properly broken up. In order to secure successful results, all dampness and dust must be avoided. Costs are almost entirely a function of the location and the character of the work and point of supply. There are so many things that enter into the question of road costs that it is exceedingly difficult to make any generalization. Frequently you see roads being built which have as much as a three- or a six-mile haul from the railroad station to haul the material used, and in such cases the expense is abnormally increased.

Mr. Clarke.—When speaking of hard roads, I had in mind a certain kind of tarvia I have seen put down. I would like to refer again to a part of my question that was not answered; that is, is it possible to re-tarviate roads and eliminate the holes?

Mr. Fulweiler.—The Metropolitan Park Board of Massachusetts has had considerable experience in repairing and resurfacing roads that have already been treated with tar preparations. Successful work seems to depend on preventing an excess of the tar compound collecting in the worn spots and depressions in the surface. The method they use is to fill the holes or depressions with ¾-inch stone before applying tar compounds. This size stone will fill holes as shallow as ½ inch very nicely, because the ¾-inch stone means that the stone has passed through an opening ¾ inch in diameter, so that that is its largest dimension, and it is usually very much smaller than ¾ inch in its other two dimensions, so that when it is rolled it flattens down on its shortest dimension, and when screenings are added and rolled the whole mass is compacted.

Some of the roads in the Metropolitan Park District of Boston, particularly the drive leading to Revere Beach, has been re-treated, I understand, three times,

and the last surface is very satisfactory. They had considerable trouble though, at first, due to excess of material, as mentioned before.

It is exceedingly important that you should have stone and not dust in the surface, as stone is required to carry the traffic. The function of the tar or oil used in road treatment is not to carry the traffic, but to bind the stone and to give a waterproof surface. The mixture of dust and tar has no stability and is soon disintegrated under traffic. The method in detail of filling these holes is, after the road has been swept thoroughly, to have a man follow the sweeper with a barrow of ¾-inch stone. He puts just a sufficient quantity of the fine stone in each little depression, taking care that an excess is not used. Considerable care is required to prevent this, as there is always a tendency with an untrained man to put in too much. This gives a surface full of bumps; in fact, care is the principal requisite for success in nearly all of this work.

PRESIDENT DALLETT.—Have you tried any of the vacuum systems of cleaning?

MR. FULWEILER.—Yes; the vacuum system has been tried; the Thwaite system does it.

T. HUGH BOORMAN.—It should be taken as a lucky omen that at the first meeting of this body, so early in 1910, the matter of good roads should come up for discussion. To all of us it is most important. To the country at large it is considered probably "the question" of the day. Railroad engineers are vitally interested in the building of the arteries which lead to their trunk lines. Every engineer, whether driving his own automobile or patiently plodding along the highway, wishes for the dustless road which adds so much to his health and comfort. Whether commercially interested or not in road building, the profession is certainly indebted to Mr. Fulweiler for the paper read this evening.

It has occurred to me that it is worthy of mention at this time that the first waterproofing application to an ordinary road was probably that in 1849, when at the village of Travers, Switzerland, pieces of asphalt rock falling from carts traveling between the mines and the mastic works compressed under the wheels and produced a road surface so serviceable that it led to the construction of a macadam road of crude rock asphalt compacted with a roller, under the superintendence of Mr. Merian, a Swiss engineer. So by an accident the discovery of a waterproof roadway was evolved, and since 1851 patents for various processes of mixing bituminous binders with mineral ingredients have been taken out. In recent years they have increased and multiplied to such an extent that one paving company is reported to hold fifty-seven rights pertaining to its industry.

From the year 1849, when, as stated, the rock asphalt laid in a crude manner gave such excellent results as a road surface, efforts have been unceasing to gain similar results of waterproof and durable streets and roads.

The first modern pavement may be considered to be the ordinary compressed natural rock asphalt streets of Paris, London, and Berlin. Then followed the sheet asphalt pavements of America, necessitated by the high freight rate from Europe on a bituminous limestone rock, of which only about 10 per cent. was bitumen.

As our modern street work came from a road discovery, so we must now endeavor to attain the best results for road building from the work which has been done on our streets. The lessons there learned would seem to point conclusively to the fact that the permanent roadway of the future must be constructed of

crushed stone, sand, and a waterproof cement with an asphalt base which will thoroughly bond the mixture into a hard and durable surface without losing its elasticity.

J. Chester Wilson.—It seems to me that in the course of road-making we are progressing toward probably an india-rubber or gutta-percha road; possibly an india-rubber inflated road. We are pushing on toward something that costs a little more at every step, possibly with a little greater comfort with each change. Some of us are interested in borough road building, where there is a limit to our treasury, and still we want to build good roads for the rich automobilists who drive over them, so that they may come out from the city and pass over our roads without accident.

I would like to know whether any one present has any idea of the relative cost of these different roads; whether these things have been reduced to the science of cost per unit of some size by which we may fix the cost per square foot or yard?

Mr. Swaab.—Does Mr. Fulweiler know anything about the particular kind of pavement that has been laid on Atlantic Avenue in Atlantic City? Some of us who have been going over that pavement recently have noticed an immense improvement over what was there originally.

Mr. Fulweiler.—I would say that the pavement in question is the Warren Bros. "bitulithic," and was laid according to their specifications, which required that the voids in the stone aggregate should be reduced to a very low figure so that a maximum of stability would be secured in the stone mixture. I can say for the work already done by the Warren Bros. under their specifications that they are exceedingly careful in their mixing and grading of the stone and in securing a uniform quality of bituminous binder. The only disadvantage in this form of construction is the fact that it is patented, and the royalty costs make it too expensive for road making.

Mr. H. E. Birkinbine.—I would like to ask if there are any methods of applying these preparations which will render the road less slippery, especially in winter weather?

Mr. Fulweiler.—The greatest trouble from horses slipping on tar-treated roads occurs in frosty weather. It does not seem to be so bad in real cold weather as it is on a frosty morning. Slipping is primarily caused by an excess of the binder at some point on the surface. In order to give the best results the surface of the road should be composed of very fine stone particles held in the matrix of the binder, which should be so distributed that there will not be an excess of the binder on the surface at any point. In investigating a slippery surface recently, I saw half a dozen horses slip, and one of them fall completely, all in the same place. It was found in every case that the slip had started on a larger piece of smooth stone that was not covered by screenings, and it was continued on patches where the binder had completely covered the surface, as there were no stones here to stop or hold the caulks. The excess of binder usually results from careless application of the flush coat, and can be remedied by a proper use of screenings on the surface. The proper surface finish is secured by the use of clean screenings applied with a hot flush coat of the surfacing material, so that the small stone will be held in a sort of mosaic with the binder.

Mr. Birkinbine.—Have you found any cases where the horses' hoofs have worn out the surface?

MR. FULWEILER.—Yes, but when the road gets down to that condition, it should have a very light coat of binder and then some more screenings spread over it. Unless quite hard screenings are used, the whole surface will wear off. Ordinarily, by the time the screenings have worn down, if they have been applied properly, the little projecting points on the under surface are working up to the top, and they in their turn act as screenings. There should be merely enough binder in the surface to separate the stone particles and bind them all together; as the road wears down, the new surface from below should come into action.

E. M. NICHOLS.—I would like to ask Mr. Hunter or Mr. Fulweiler whether it might not be possible to arrive at some basis on which the motorist might be proportionately taxed for his use of the roads. By what I can see of it, the masses of the people pay the road taxes for the benefit of the automobilist, who makes the most use of the road and is not taxed very much more than anybody else. In other words, a road used by automobilists requires a greater expense to maintain, and the people as a whole pay the taxes.

MR. FULWEILER.—Will Mr. Hunter please state whether his run of crusher stone for the mixing method does not depend considerably on the way the crusher is set and the kind of stone that is being used, as I have found that some run of crusher stone would not work at all in the mixing method, as the stone came out far too uniform as to size, whereas at other times it seems to be very nicely graded.

I think I can go Mr. Boorman one or two years better on his first waterproof road. I did a considerable amount of digging in the literature a year or so ago, and found that, what I believe was the first waterproof road, was made in the city of Nottingham, England, about 1842–44. The manager of the gas works at that place noticed that where the tar from the hydraulic main had been carried out by hand to the tar tank, the drippings which had spilled on the cinder walk had hardened, solidifying the path into an impervious pavement, so he tried this method of mixing tar and clinker on a short stretch of road in front of his office. This, I think, was actually the first waterproof road.

About the concrete expansion joints: There have been a number of attempts to use the cheaper methods and fill up the joints with asphalt, or to provide a metal edge to the joint. There is one system in which they use a piece of angle-iron.

MR. SWAAB.—How far apart would they put those joints in the length of the street?

MR. FULWEILER.—In my opinion they are not necessary, but they seem to be placed from 25 to 50 feet apart. I know I saw one road which did not have a joint in it; it was five or six hundred feet long, and it seemed to be all right. I do not know where that strain goes to.

I am afraid I must differ with Mr. Hunter to some extent where roads are merely watered, even if the automobile traffic is kept down to 15 miles an hour, because the horizontal shear due to the torque of the motor may assume its maximum value when the machine is first starting and has not attained a speed of 5 or 10 miles an hour, and it may also rise to its maximum value on sharp curves at fairly low speeds, owing to the fact that the differential gears in the rear axle frequently do not work properly, so that there is nearly always more or less drag on the tires in rounding curves.

As soon as we bring our ordinary country roads up to a higher standard, the

motor truck and other motor-driven commercial vehicles will be used here as they are in England, as their use is an important factor in reducing costs. The great difficulty is the fact that they cannot climb much of a grade without rubber tires, or some form of non-skidding device. They are now trying to construct them with a drive on all four wheels in order to use the smooth steel tire. Their destructive action on roads is caused by the grids on the wheels shearing the surface whenever the top car turns from a direct line. This digging action has caused considerable damage already to the English roads.

With regard to costs, there have been a number of articles published by some French engineers in "Les Annales des Ponts et Chausses," in which curves are shown of the allowable cost of treatment based on the traffic the road has to bear. In considering these curves for a great many roads, the surface treatment seems to be very economical, but it must be remembered that in England and on the Continent they use machines for spraying the tar, and thus apply only a very small amount per square yard, so that their cost works out to from 1 to 3 cents per square yard, which is less than half of what it is here.

Mr. Boorman.—Has Mr. Fulweiler any record of the length of time that the Nottingham road was in good condition? In reference to my 1849 road, I have record, that M. Leon Malo located that road in Travers in 1866, and found it was then in comparatively good condition. I hardly think that the tar drippings would have given an equally satisfactory bond to the road or walk on which they fell.

Mr. Fulweiler.—I cannot tell you anything about that road, except from the printed record, but there is a tar road built up in New Hampshire, in practically the same way as the walk referred to, with tar from a gas works, which has been down about twenty-eight years, and is still giving pretty good service. I think the road Mr. Boorman referred to was down about nineteen years.

PAPER NO. 1084.

THE DISINFECTION OF WATER AND SEWAGE.

EARLE B. PHELPS.
(Visitor.)

Read January 15, 1910.

THE subject of disinfection of drinking-waters and of sewage is in no sense a new one. Almost as early as the nature of infectious diseases and the methods of their communication became known, through the developments of modern bacteriology, the desirability of disinfecting waters in particular was recognized. Attention was first drawn to the practical possibility of such processes through the work of early investigators in connection with the water-supplies of troops in the field. Without going into details of these investigations, it will suffice for our present purposes to note that many disinfecting processes were developed by workers in England, Germany, and France. These processes depended, in the main, upon the application of prepared pellets of the various disinfectants employed, and in general involved the addition first of the disinfectant itself, and later of one or more neutralizing compounds, by which the active disinfectant was destroyed and harmless chemical products alone remained in the water. Compounds of chlorin, bromin, and iodin, copper salts, permanganate, and many other powerful disinfectants were employed in this way. On the whole, remarkably successful results for the purpose in hand were attained, but the processes were necessarily limited to small volumes of water, and were totally unsuited, owing to the nature of the reactions and the cost of the material employed, for application to large city supplies; consequently for many years attempts to purify domestic water-supplies have been confined in the main to sand filtration methods which are now so well known that their discussion at this time is uncalled for. It may be pointed out that these processes are in reality disinfecting processes, since in most cases their chief aim is the removal of pathogenic germs. In the course of the rapid and well-nigh universal development of filtration processes, however, the basic principle of chemical sterilization has never been completely lost sight of. Great stimulus was given to these ideas about a decade ago by the develop-

ment of commercial processes for the production of ozone. The well-known germicidal properties of this oxygen compound, coupled with the fact that its end-product is ordinary atmospheric oxygen, make the process an ideal one from a chemical and physiological point of view. Commercially, it has always been hampered by the relative high cost of production, by mechanical deficiencies in the machinery necessary for such production, and by certain physical difficulties attendant upon the introduction of the ozone into the water. Therefore, despite the fact that progress in the ozonization of water has been consistent and quite rapid, yet the use of ozone in water disinfection has not become general. It must be particularly noted, however, that the deficiencies of this process are purely mechanical, and that the work of investigation which is going on in many parts of the world may reasonably be expected eventually to develop a process as successful commercially as it is ideal from purely sanitary considerations.

Quite early in the history of the chemical disinfection of water the possibilities of chlorin compounds were recognized. Electrolytic processes for the manufacture of these compounds were developed as early as in 1889, when Webster in England and Woolf in this country attempted the use of electrolyzed sea-water solutions in disinfection work of one kind or another. Here again mechanical difficulties were met with which, combined with the fairly high cost of production, prevented the general adoption of these methods. The commercial production of calcium hypochlorite or bleaching powder had in the meantime been developed to so high a degree of efficiency, owing to the great commercial demand for this product, that sanitarians soon had at their command an extremely efficient disinfectant which could be obtained in any desired quantity at very moderate cost. Attention therefore was early directed to the possibilities of this commercial product, particularly in connection with sewage disinfection. As early as 1854, the Royal Sewage Commission of Great Britain recommended the use of this substance in deodorizing the sewage of London. In 1885 the Special Committee of the American Public Health Association carried out an exhaustive study of all available disinfecting materials, and found that hypochlorites in general were the most efficient substance that could be used, cost being considered. In Germany, at the Hamburg Hygienic Institute, the work of Proskauer and Elsner in 1897, and later of Dunbar and his associates in 1904 and 1905, demonstrated anew the

possibilities of hypochlorite of calcium in sewage work, with special reference to disinfection rather than to mere deodorization. At the Royal Testing Station at Berlin work carried out in 1906 confirmed the Hamburg results, and indicated that the disinfection of sewage by this means was entirely feasible. Rideal's experiments at Guilford, England, made about the same time, practically confirmed the German results.

All of these investigations, and more particularly those made in Germany, had reference to the emergency use of chemical disinfection during epidemics, especially of cholera. In such situations questions of economy do not usually arise, and, with their usual thoroughness, the German experts established standards of purification so high that their processes, although eminently satisfactory under the conditions for which they were devised, were still too costly for ordinary every-day use. It remained for the investigators of this country to demonstrate that much lower percentage efficiencies than those obtained previously would still suffice in routine work, and that the cost of obtaining these sufficiently satisfactory results would not be prohibitive. These conclusions were first reached as a result of investigations carried out at the Sanitary Research Laboratory of the Massachusetts Institute of Technology, with which the writer has the privilege to be associated. These studies, which were begun in 1906 and extended over a period of two years, were made possible by the generous co-operation and financial assistance of the United States Geological Survey. They were shortly followed by studies made by Kellerman, Pratt, and Kimberly for the United States Department of Agriculture and the Ohio State Board of Health. The first practical demonstration of the use of bleaching powder on a large scale was made by the State Sewage Commission of New Jersey at Red Bank, under the speaker's supervision. The work was started in October, 1906, and carried on during the fall and a portion of the following summer. Two hundred and fifty gallons of sewage per day were treated at this place. About this same time the writer was retained by the Baltimore Sewage Commission to carry on experiments at Baltimore looking toward the disinfection of the final effluent of the proposed trickling filters now being built at that place. Since that time numerous investigations have been made in all parts of this country, and many working plants have been installed or are now in process of installation. Without exception, the conclusions of the early Massachusetts experiments

have been confirmed, and for the first time in the history of chemical disinfection, it has been amply demonstrated that sewage may be thoroughly disinfected at a cost which is not disproportionate to the cost of other purification processes.

Briefly, then, this is the history of the development of chemical disinfection. At the present time the most serious problem is not how to disinfect sewage or water, but rather under what conditions such disinfection is called for, just what the process accomplishes and under what amount of supervision it must be carried out. There is grave danger that, through ignorance of the essential aims and actual accomplishments of this process, it will be misused or employed in situations where its use is uncalled for. Therefore this opportunity to explain the particular work which the process may be expected to accomplish, the peculiar conditions under which it may be properly applied, and its severe limitations, as a general method of sewage treatment, is especially welcome. It must be pointed out at the very outset, and will be reiterated throughout the course of this paper, that the chemical disinfection of sewage or of water is not a panacea. Except under strictly limited and peculiar local conditions it is not even a substitute for other purification methods. In general, it may best be described as an "adjunct," or, to use a term familiar to engineers, "a factor of safety." To the extension and development of this idea, and to a discussion of the actual place of disinfection in sewage and water work, these remarks will be chiefly addressed.

The recent revival of active interest in the possibility of chemical disinfection took place, first, in the field of sewage disposal, and later spread to water purification. It may be well to maintain this order of development, and to consider first the chemical disinfection of sewage and of sewage filter effluents.

Disinfection of Sewage.

Sewage consists of about 999 parts of pure water and 1 part of impurity, about one-half of which is organic impurity and bacterial life. Sewage disposal deals with this five one-hundredths per cent. A perfect process of sewage disposal may be defined as one which totally removes and finally oxidizes to a mineral form this very small proportion of organic matter. The slow sand filter, developed to its highest degree of efficiency, can be relied upon under specially favorable conditions to practically accomplish this result. It is possible to produce by such means a water fit for domestic purposes.

The cost of such treatment is high even under the most favorable circumstances, where, as in the case of the Massachusetts towns, large areas of suitable sandy soil are readily available. In less fortunately situated locations, and always among the larger cities, the cost of such a process would be prohibitive. Therefore the tendency of the times as illustrated by the work of experiment stations, and by the effort of municipalities along these lines, has been toward more rapid and less perfect processes. Unfortunately along with this tendency there has come another tendency, namely, toward the standardization of processes, by which is meant a tendency toward the adoption of certain settled types of works regardless of the local requirements. This is a result in part of the unwillingness, and at times the inability, of communities to undertake special investigations of their own or to employ expert assistance. It results also in part from the unfortunate disposition of certain of our State authorities to demand this kind of uniformity throughout their jurisdiction. We have therefore a situation which might be amusing if it were not so serious, in which a designing engineer learns by experience that any plan submitted by him in certain jurisdictions will not receive the necessary sanction of the proper State officials unless certain standard features are incorporated; whereas he is equally well aware that in a neighboring State no plan will be approved which embodies these same standard features. The fact cannot be too strongly emphasized that the solution of any particular sewage disposal problem is one which depends mainly upon the requirements of the local situation. The only conceivable general solution of the problem would be perfect purification, such as has already been defined, and even if this were desirable the result might be obtained by two or more different methods. In general, such purification is unnecessary, and insistence upon it would be a grievous mistake. If partial purification methods are to be allowed, then surely they must be adapted to the requirements in each case. Therefore your attention is first directed to the nuisance which lack of sewage disposal may bring about in order that the method of abatement may be indicated.

One serious nuisance which may follow the introduction of crude sewage into a body of water is the deposit of solid material. Such material we describe as "suspended matter" in the sewage, and one of the classes of treatment to which attention is most often directed has in view the removal of suspended matter from the sewage and the prevention of this form of nuisance. Obviously, now, if the

stream is swift and the dilution large, or if the discharge be made into rapidly moving tidal currents, this nuisance will not occur, and special treatment for its abatement will be unnecessary and unwise. Under reverse conditions of discharge into slowly moving streams, particularly into streams which are dammed, or bodies of water which are shallow and do not possess strong tidal currents, the possibility of deposit upon the bottom is one which must be dealt with, and the removal of suspended matter from the sewage must be accomplished to a greater or less degree.

The second kind of nuisance is that which results from the putrescible character of sewage, regardless of whether the organic matter is suspended or in true solution. This is the property of sewage matter by which it robs a stream of its available oxygen, and consequently of its power of self-purification. Under these conditions fish life is destroyed, noxious odors arise from the water, and the stream becomes virtually an open sewer rather than merely a polluted water. The line between these two conditions is a distinct one. The capacity of any stream to absorb sewage and maintain its own aëration is limited and calculable. If this capacity is exhausted, a very definite change in the character of the water occurs and the conditions above outlined result. The treatment of these conditions must be very different from that outlined in the first case. The question of suspended matter may or may not be a factor, but in this case the organic matter must first be oxidized and rendered stable or non-putrescible. The process of oxidation may go on independently of, or in connection with, any other processes, according as one or more of these classes of nuisances is possible.

The third special class of nuisance, and one which refers to public health rather than to public convenience, is the ever present possibility that pathogenic bacteria may be contained in the sewage. The extent of this danger need not be argued, nor is it desirable at this time to take up the somewhat debatable question of the efficiency of our ordinary sewage purification processes in destroying such bacteria. Somewhat divided opinions upon this question are held. The most exhaustive study of the problem that has yet been made was carried out by Houston under the auspices of the Royal Sewage Commission of Great Britain, as a result of which it was concluded that "the biological processes at work in the filters were not strongly inimical, if hostile at all, to the viability of pathogenic germs." It is the speaker's opinion, based upon all the available

evidence and upon a long personal experience with investigations of this character, that the removal of pathogenic germs by rapid filtration methods is not greater than would be accomplished naturally in the streams in an equal period of time. That such removal is considerable is frankly admitted. In the course of a few hours or of a day, under natural stream conditions, great improvement is always noted. This improvement, however, has not been sufficient to prevent the disastrous typhoid fever epidemics of Lawrence, Mass., Butler, Pa., Ithaca, N. Y., and other places too numerous to mention. If, therefore, there be any danger in the possible discharge of pathogenic germs into the stream in question, this danger must be considered by itself, and distinctly apart from the possible nuisances already mentioned. It is upon the solution of this particular problem that chemical disinfection directly bears. Whether or not nuisance may arise from the discharge of suspended matter or from the discharge of putrescible matter will determine the type of purification process necessary; whether or not it is desirable to prevent the possible discharge of pathogenic germs into the stream will determine, and must alone determine, the advisability of disinfecting the sewage or the treated effluent.

Emphasis has been laid upon these few general principles, because curiously we are better advised at the present day as to the methods of disinfection than we are as to its necessity. As has been previously stated, there is more danger that the possibility of disinfection will be misunderstood and that processes will be used as a substitute for other essential processes than that it will not be employed when necessary. The various methods of chemical disinfection which have from time to time been proposed have been fully described in another place, and need not be referred to here in detail. Suffice it to say that the application of commercial bleaching powder has been found to be by far the most efficient and practical process, and that such application has now been developed to such a point that its cost is not at all out of keeping with the benefits to be derived.

Bleaching powder is an impure commercial product manufactured in large quantities abroad by some of the earlier chemical methods, and in this country at Niagara by modern electrolytic methods. Owing to the fact that in the latter case it is essentially a by-product of the much more important caustic soda industry, its present market price is very low, and in fact less than the cost of production on a small scale. Upon admixture with water it goes into solution only

partially; a residue of carbonate of lime and an excess of free lime remaining in the tank as a white sludge. In practice it is desirable at larger works to keep this mixture stirred up and to discharge the sludge with the solution; at smaller works economy indicates the use of the clear solution and the disposal of the lime sludge in a convenient manner. To the layman one of the most striking features of this process is the relatively small amount of disinfectant necessary. For crude sewage an amount of so-called "available chlorin" equivalent to about five parts per million parts of sewage, which amounts to about 125 pounds of bleaching powder per million gallons, suffices. Upon the present market price of $25 per ton or less, it will be seen that the cost of bleaching powder necessary will be in the neighborhood of $1.70 per million gallons of sewage disinfected. By the use of the quantity indicated, disinfection is accomplished within a very few minutes, and storage periods of not over thirty minutes are ample. Sewage stronger than the average American sewage would require somewhat larger amounts than these indicated, but twice the quantity probably represents the maximum. For partially purified effluents, such as those resulting from trickling filters, lesser quantities are sufficient. At Baltimore three parts per million of available chlorin, or 75 pounds of bleaching powder per million gallons, were found effective in the disinfection of the trickling filter effluent. At Boston satisfactory disinfection of a similar effluent was accomplished through a period of six months by the application of three and a half parts of available chlorin. Effluents of a higher degree of purity can be disinfected with corresponding smaller amounts. The total cost of the processes, including interest charges and depreciation upon the necessary fixtures, labor, and other items, will range from $1.00 or less in the case of effluents to about $3.00 in the case of crude sewages. These details are given in the accompanying table. The results, which have been described as satisfactory, are numerically expressed by removals of the total bacteria, averaging 97 per cent. in the case of effluents and 99 per cent. or more in the case of crude sewage. In the former case the combined efficiency of the filter and the disinfection will bring the figure up to 99 per cent. or more. Special studies have also been made in this connection to show the probable effect upon typhoid fever germs as compared with the effect upon the total bacterial content. The indication has been that the former are affected to fully as great an extent as the latter. They are probably more completely removed.

ESTIMATES OF THE COST OF OPERATION OF A PLANT FOR DISINFECTING SEWAGE OR EFFLUENT WITH CHLORID OF LIME, BASED ON A CAPACITY OF 5,000,000 GALLONS A DAY.

Available Chlorin, Parts per Million.	Bleach, Pounds per Mil. Gal. (Approx.)	Time of Contact, Hours.	Cost per Million Gallons.					
			Fixed.		Operating			Total.
			Storage Tanks.	Other Fixed Charges.	Bleaching Powder.	Labor.	Power.	
1......	25	5.0	$0.10	$0.02	$0.30	$0.10	..	$0.52
2......	50	2.5	.05	.04	.60	.10	..	.79
3......	75	1.6	.04	.05	.90	.10	$0.02	1.11
4......	100	1.2	.03	.07	1.20	.10	.02	1.42
5......	125	0.8	.03	.08	1.50	.10	.03	1.74
10......	250	0.5	.02	.16	3.00	.15	.06	3.39
15......	375	0.5	.02	.24	4.50	.20	.09	5.05

Disinfection of Water.

Considering now the application of these same methods to the water problem, it may be said in brief that the principles involved are identical. Whether or not the chemical disinfection of water is desirable in any given situation must be determined upon principles similar to those already laid down. If the result desired is the simple removal of germs, this process probably represents the cheapest and perhaps the most desirable one now available. The word "perhaps" is inserted here advisedly. The question of just how desirable this treatment may be is one which must be submitted eventually to the consumer who pays the bills. There is a popular objection to the addition of chemicals to drinking-water. This objection was raised most seriously against the use of alum, but has largely disappeared, as the use of alum has become more and more common and as no ill effects have been developed. However harmless certain chemicals may be considered in the minds of those best qualified to judge, and however ill directed popular clamor against their use, it must be admitted that it is a legitimate consideration to be dealt with. Whether or not actual harm will be done is one matter; whether or not the purchaser of the water desires to have small amounts of chemical substances added to his supply (especially if he is willing and able to pay for more expensive processes which do not involve the use of chemicals) is quite a distinct matter. Assuming, however, that, as in the case of alum, any feeling which may be developed at present will disappear in the course of time, it

is certainly true that under certain circumstances the chemical disinfection of water may be used to great advantage. As in the case of sewage, so also in the case of water, special consideration must be given to the primary needs of the situation. Disinfection merely kills the germs; if this is all that is required, then disinfection is indicated; if the removal of organic matter from a water seriously polluted with sewage is deemed advisable, then some other process must be employed. If that process is efficient also in the removal of germs, disinfection is uncalled for. If that process, on the other hand, is insufficient, or if economy indicates that it may purposely be made insufficient,—through the use of high rates of filtration, for example,—then disinfection may be advantageously employed to supplement the imperfect process. The two great fields which are open to water disinfection are the treatment of a very slightly or only occasionally polluted supply by disinfection alone, and the treatment of a more seriously polluted supply by the present methods at highly increased rates and by subsequent disinfection. In the latter case disinfection will be found a valuable adjunct to overloaded mechanical filters. The limiting rates of operation on slow sand filters are determined largely by the organic content of the water and by consequent economy in the expensive cleaning processes. The limiting rates on mechanical filters, on the contrary, are practically determined by the necessity for obtaining bacterial purification. Therefore it is especially with reference to this latter type that disinfection will be found important.

Although, as has already been indicated, the chemical disinfection of water has been practised from time to time at various places, the first notably successful plant in this country at least, and the one which is directly responsible for the present favorable consideration which this process has acquired, was constructed and operated early in 1908 by Mr. George A. Johnson, of New York city, at the Chicago stockyards. At this plant the highly polluted water of Bubbly Creek was treated first by chemical precipitation and then by means of bleaching powder. The results of this undertaking were highly satisfactory. Later Hering & Fuller, of New York city, of which firm Mr. Johnson is a member, were called upon to construct at Boonton, New Jersey, on the Jersey City water-supply, a plant for the complete disinfection of forty million gallons of water daily. This plant, which has been in operation since September, 1908, has been so fully described in various papers by Dr. Leal, who is primarily

responsible for its installation, by Mr. Fuller, and by Mr. Johnson, that it will be unnecessary to discuss it in detail at this time. It is sufficient to note that the water in question is the somewhat polluted water of the Rockaway River, which has received the advantages of storage and sedimentation in its passage through the immense Boonton reservoir. The results of the continuous operation of this plant have been eminently satisfactory. It might be stated here that the recent litigation in connection with this plant had to do with certain contract requirements rather than with actual results achieved. In Mr. Johnson's report of the operation of the plant it is shown that the bacteria in the water before treatment ranged from a few hundred to a thousand or more, whereas after treatment the water was often found to be sterile, and contained, as a rule, not over ten bacteria per cubic centimeter. The bacillus coli was reported present almost uniformly in the raw water in 1 c.c. tests, and was seldom or never found in the treated water. Quantities of available chlorin not exceeding 0.3 part per million, or eight pounds of bleaching powder per million gallons of water treated, were found efficient. Mr. Johnson estimates the total cost of treatment, including additional labor required, at 14 cents per million gallons. The successful outcome of this great and novel undertaking has resulted in the introduction of this process in at least thirty localities in the eastern United States. The speaker has recently completed the installation and three months' study of a small plant used in connection with mechanical filters. Quantities of available chlorin ranging between 0.25 and 0.4 parts per million were found necessary, and results substantially like those already quoted were obtained, in spite of the fact that the raw water contained at times several thousand bacteria per cubic centimeter.

Here again, as in the case of sewage, the danger is that this process will be misused through a lack of understanding of its possibilities and its rightful field. It is not in general a substitute for filtration. It may be that filters are used where germ removal is all that is necessary. Such filters could be replaced by disinfection methods at an immense saving in the cost. A further danger, which is not so conspicuous in sewage work, lies in the use of this process by inexperienced persons. The proper regulation of the necessary amount of material does not require expert supervision at all times, but the question of how much disinfectant to employ in any given situation, and of the proper method of applying it, and other details of the

operation, should in every case be submitted to expert judgment. In addition, the routine operation of the plant should be safeguarded in such a way that the possibility of mistakes should be minimized. As little responsibility and as little chance to go wrong as possible should be left to the operator. In other words, the operation should be made as nearly fool-proof as possible. With these safeguards properly applied, and under the conditions which have been outlined, it can safely be said that a new epoch in water purification methods has begun, and that the methods developed and introduced by Dr. Leal and Mr. Fuller, and especially by Mr. Johnson, have already established their rightful place in the ever growing field of water purification.

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DISCUSSION.

F. Herbert Snow (Harrisburg).—As you know, there is a Pennsylvania law enacted at the last legislative gathering which prohibits the use of alum and copper compounds in food-stuffs. It may be found under one of the sections of the Pure Food Act. The question of whether this law can be extended to apply to treated waters supplied for public uses is a mooted one. It has received some minor consideration, and was the subject of particular inquiry at the time the bill was before the legislative committee. I believe it was generally accepted that the bill if it became a law would not be applicable to mechanical filtration plants where the purification of the water is accomplished in part by the introduction

of chemical solutions for the purpose of coagulation and precipitation. Nevertheless, there are occasional and persistent rumors that the law does in fact apply to water, and that alum, if found in water supplied for public uses, is administered contrary to the provisions of law.

It has come to be an accepted fact, generally speaking, that the use of alum compounds as a coagulant in the preliminary treatment of water is unattended with any possible danger to public health where the preparation of the chemical solutions and their introduction into the raw water is accomplished under the supervising direction of a competent person. Nevertheless, I believe that there are many water consumers throughout the towns of Pennsylvania who still adhere to the opinion that this use of alum is a menace to public health, and no amount of proof would convince some of them that this was not so. In fact, there have been known cases where the raw water was not capable of absorbing the chemical solution of alum compounds, and undoubtedly the solutions reached the homes of the consumers substantially in the forms in which they were introduced into the water, although highly diluted. To prevent such carelessness the Commissioner of Health has established a State supervision over all water purification plants in Pennsylvania.

The use of bleach in public water-supplies must bear to the public mind a relation similar to that of the use of alum. The State has discouraged the general application of chlorinated lime to drinking-water. However, in one instance, that of the city of Reading, the Commissioner has approved of the treatment of raw water with hypochlorites of lime under the skilled attention of the city's bacteriologist and chemist, pending the completion of a slow sand filter plant, which will be in operation possibly twelve months hence. Perhaps these few remarks are all that I ought to offer on the subject, in consideration of the position I now occupy. I came here to learn what Professor Phelps might have new to offer on the subject, since he is working in this field all the time. I might add that should you peruse the decrees of the Commissioner of Health relative to sewerage and sewage disposal since 1905, you would observe in the conditions and stipulations under which plans have been approved the provision, sometimes specifically stated, for the treatment of the effluent with some germicide. At Mt. Alto, where the State sanatorium for the treatment of tuberculosis patients has been built by Dr. Dixon and is now being operated, the effluent from the sewage works has been treated with a solution of bleach since the outset, with the result that not one sewage organism has been found in the final effluent.

George S. Webster.—It is hoped that the investigations of the use of disinfectants that have been carried on so extensively by Professor Phelps and his associates at the Massachusetts Institute of Technology will greatly simplify the problem of sewage purification, particularly in cities which have large streams of water near at hand. Any method which will tend to simplify the treatment of sewage will no doubt decrease the cost of disposal.

If the solids contained in the sewage can be removed mechanically and the bacterial life destroyed chemically by the addition of a solution of bleaching powder, and results obtained at a reasonable cost which will be acceptable, much has been accomplished to aid the profession in handling this important problem.

Geo. E. Datesman.—I do not know that I can say anything to add interest to the meeting, except that the city of Philadelphia has for the last nine months

been operating night and day, twenty-four hours every day, Sundays included, an experimental plant that follows as nearly as possible the working conditions that will obtain in a full-sized plant. Various processes have been under observation and almost everything that has been advocated has been tried. A great many things have been eliminated after trial, and it only remains to complete the full cycle of seasons to determine certain fluctuations and certain other factors which may be applied in the design and construction of a full-sized plant, as far as the local conditions are concerned. But these factors cannot be taken as applying to other conditions unless the character of the sewage and the other problems that arise are similar.

Something has been done in the way of disinfection, principally in finding out mechanical difficulties. We have not yet determined the minimum amount of bleach that should be added to obtain satisfactory results, but are hopeful of accomplishing this in a short time. As Professor Phelps has said, "there are certain difficulties which arise in the application of bleach through small orifices, due to the deposits of a calcareous nature in the receptacle, appearing as a white sludge and almost in quantity as much as the original bleach," if I am quoting him correctly. We found this to be true, and made no less than five different devices to overcome it, and owing to the persistence and ingenuity of the engineer in charge of the testing plant, I feel sure he has accomplished it. I am led to make this statement because a member of one of the largest consulting engineering firms in this country was very glad to accept the suggestion and apply it to one of the plants of his own design. We find that bleach attacks brass, iron, platinum, and other metals, and corrodes them very quickly. Even lead, which is attacked less than other metals, suffers in time. This is an important thing in a large plant, and it is hard to determine just what should be used. Vulcanized rubber and glass seem to resist the corrosive qualities, and we have had some little success with fiber.

I feel sure, gentlemen, that Professor Phelps, in his work, has conferred a distinct benefit upon the engineering profession and upon the general public of this country. I am led to this statement not only from the perusal of his articles and having become somewhat familiar with his experiments, but from the view that has been taken by others. I find, in reading foreign periodicals, that the English search with the greatest avidity for anything that comes from his pen, and his writings are spread broadcast throughout the kingdom of Great Britain. I think as Americans we should look with pride on an achievement of this character.

While the modern sewage problem was conceived by an Englishman, it was not until the Massachusetts State Board of Health took up the question and investigated it systematically and made experiments to see what could be done under varying conditions that it was reduced to a commercial basis. The results of those experiments have been gratifying, although on such a small scale. It has been said, however, that if they had a small filter about the size of the secretary's table, they could write a book about it about twice as large as the filter.

Nevertheless our English cousins have taken these experiments of the Massachusetts Board and backed them with millions of dollars to carry out those experiments on a large scale, and to-day all honor is given to their American cousins who have carried out these investigations.

Our government and Board of Health investigations have decided that the bleach is quite the cheapest and most effective germicide. I trust that the investigations will be carried along until we become more positive in the methods of application and may know when to apply it in any method of sewage purification.

There is one other little matter: Professor Phelps says he does not advocate the application of bleach as a panacea or a substitute for other purification processes. He is very modest to make this statement. Many people are carried away by ideas that appear to them as convincing. It does not appear to be so in Professor Phelps' case. But as a matter of satisfaction, I wish to state that the application of this bleach as an experiment sometimes produces unexpected results. During the past week we were driven to the use of bleach for the preservation of our bacteria beds. Our beds were filled with a sludge impermeable to liquids for a depth of perhaps 2 feet. A quantity of bleach, of which I cannot now recall the figures, was put in, and a repetition of the process two or three times was successful in that it restored the beds to their original condition, and while I am not yet able to say whether it lowered the bacterial efficiency, there is no doubt but that on a large sized plant an application of this kind would save several thousands of dollars, and by the knowledge of the efficacy of such application many units can be maintained in service that would otherwise have to be built as an extra precaution.

Henry Leffmann.—The principles applicable to the use of aluminum compounds in food cannot be applied to the use of these compounds in the purification of water, because the aluminum, in most cases, remains in some form in the food; but, in the proper operation of water purification, none is found in the effluent. The practical difficulty in reference to all systems of purification with coagulants is in regulating the supply of the coagulant. This is generally attempted by use of automatic apparatus, but is by no means always successful. I presented some time ago to the Philadelphia Section of the American Chemical Society a short paper, giving data in regard to the operation of an alum-filter plant in one of the large hospitals in this city, showing, by the tests of the effluent in comparison with the applied water, the great irregularity of the alum-feed.

Aluminum sulphate is the coagulant generally employed, and it must not be overlooked that this, by increasing the sulphates in the water, increases the tendency to form a hard scale in boilers.

P. A. Maignen.—As a matter of history I think the name of L'Hermitte should be mentioned. He was probably, after Webster, the first to use hypochlorite in France.

I would like to ask Professor Phelps if he has any information on the taste of the water after it has been treated with bleach and passed through a sand filter. Whether the chlorin does not remain hugging the grains of the filtering materials and afterward give a bad taste to the water?

I am very glad that the subject of the chemical purification of water and sewage has been presented to this Club. I do not know if anybody has anticipated me in demonstrating that the chemical purification of water brings about *ipse facto* its sterilization. This was done in the year 1890.

The facts that have been mentioned to-night by the Professor and by the last speaker must put a fly in our ear about the use of bleaching water. If this

material acts so strenuously on metals, even attacking platinum, it behooves us to think that there may be some serious danger in its use.

The prejudice against alum is not based on its use, but on its abuse. The same may be said of the use and abuse of bleach. This objection has always been made and will always exist unless it can be proved that an excess, however great, of the chemical cannot do any harm.

The study of the chemical purification of water deserves our closest attention. It should not be resorted to just to help a filter, as is the case when alum is used with so-called mechanical filters. Chemicals should be selected to purify the water independently of filtration and as if no filter whatsoever were to be used. We ought to spend our money on that which is necessary, namely, the material which does the work, and not in accessories.

There is no reason to limit ourselves to alum or bleach; you have the whole gamut of chemicals from which to choose. Suit the chemical to the particular water or the particular sewage to be treated. Lime, for instance, has been used in sewage purification abroad for a very long time, and it is still used in many places because it is safe and cheap. One of the objections urged against the use of lime in sewage treatment is that it makes a great deal of sludge. But lime plus sludge, if collected, would make a pretty good fertilizer.

One may perhaps not be justified in opposing the use of bleach as a disinfectant for sewage, because the treated sewage is mixed with a large volume of water and there is probably not enough of the bleach left to be appreciable. But I cannot conceive its satisfactory use for drinking water. A small quantity of the chlorin gas in the water passing through filters day after day must ultimately leave traces of the sand, which may give a bad taste to the filtered water long after the chemical has ceased to be added to the applied water.

The subject is well worth being studied by chemical engineers. Do not think that bleach or alum are the only available chemicals. Select the chemical that will do the work in a perfect manner. When entering upon the consideration of a problem of this kind, first ask: Is it wanted? Can it be done? Last of all, How much will it cost? If you put the last question first, you will never make any progress.

We are very much indebted to Professor Phelps for having brought the matter before us this evening. If disinfectants are necessary for water or sewage, they should not be added in the dark, but in broad daylight; not with an apology, but because they do the right kind of work and do it safely.

Mr. Phelps.—Replying to Mr. Maignen's question about the odor, I may say that the odor is a very serious matter to be dealt with. If we get too much bleach, we get an odor anyway. If there is too much organic matter, we are pretty sure to get the odor if we put in the bleach before it goes to the filter. It is not a chlorin odor; it is what we call a vegetable odor. We get around the difficulty by adding the bleach after filtration, and I think that is, on the whole, the best place to add it.

M. R. Pugh.—I would like to ask Professor Phelps whether he has made any investigation as to the effect of bleach on sewage before entering the bacteria beds. I believe that Dr. Dunbar has done some work in that direction in which he found it did not have an injurious effect on the bacterial action, and there were cases in which he seemed to think that an application of bleach before it went

through the bacteria beds was more effective than applying it to the effluent finally.

Mr. Phelps.—We have not repeated those experiments. The speaker was correct in quoting Dr. Dunbar. I could never see any reason for doing that. I think the work recently done in Germany was done that way because they had settling tanks in which the sewage was settled before filtration, and they did not have tanks for treatment afterward. We have never followed any such process, because our present system saves about half the bleach.

ANNUAL REPORT OF THE BOARD OF DIRECTORS,

For the Fiscal Year 1909.

January 29, 1910.

TO THE MEMBERS OF THE ENGINEERS' CLUB OF PHILADELPHIA:

The Board of Directors hereby presents its report for the year ending December 31, 1909, as follows:

Eighteen stated and two adjourned meetings of the Club were held, at which the maximum attendance was one hundred and seventy-nine, and the average one hundred and twenty, a decrease in average attendance of twenty-two members compared with 1908, and an increase of thirty-four compared with 1907. The adjourned meetings were not included in computing the average attendance, as they were called to discuss proposed amendments to the By-Laws, and no papers were presented.

Ten stated, one adjourned, and eleven special meetings of the Board of Directors were held. The summary of membership on December 31, 1909, compared with the summary of December 31, 1908, is as follows:

CLASS.	1908.			1909.		
	Resident.	Non-Resident.	Total.	Resident.	Non-Resident.	Total.
Honorary......	1	3	4	2	2	4
Active.........	442	103	545	411	97	508
Associate......	52	2	54	51	2	53
Junior.........	38	4	42	50	9	59
	533	112	645	514	110	624

Nineteen active, ten associate and thirty-five junior members were elected; one active member was transferred to the honorary grade; one associate to the active grade; eleven juniors to the active grade, and one junior to the associate grade; one honorary and five active members died; thirty-nine active, nine associate, and five junior members resigned; twenty-five active, two associate, and three junior members were dropped from the rolls, and two active members were reinstated to membership.

The report of 1908 was incorrect, in that two resident junior members were omitted. This number, therefore, should read forty, instead of thirty-eight, and the total should be six hundred and forty-seven, instead of six hundred and forty-five.

The record of deaths is:

Wm. Price Craighill, Honorary Member, died August 18, 1909.
Frederick Stamm, Active Member, died March 1, 1908.

Alexander Murrie, Active Member, died March 19, 1909.
Wm. P. Henszey, Active Member, died March 23, 1909.
C. T. Wunder, Active Member, died May 28, 1909.
George T. Barnsley, Active Member, died October 23, 1909.

The following papers have been presented before the Club:

January	2.	"Discussion of Strength of Beams." H. D. Hess (Active Member).
January	16.	Annual Address. "Training in the Engineering Trades in Philadelphia." President H. W. Spangler.
February	6.	"Recent Improvements in Gas Lighting Apparatus." T. J. Litle (Visitor).
February	20.	Discussion on "Topics Connected with the Disposal and Purification of Sewage." Opened by F. Herbert Snow (Visitor).
March	6.	"Hammerstein as a Builder." Manton E. Hibbs (Active Member).
March	20.	"Metal-planing Machines." George H. Benzon, Jr. (Active Member).
April	3.	Demonstration of Wireless Telegraphing and Telephoning. A. Fred. Collins (Visitor).
April	17.	"Interurban Railways." Benjamin Franklin (Active Member).
May	1.	"The Sanitary Control of Filter Plants." Francis D. West (Visitor).
May	15.	An Informal Talk on Caisson Foundations for Bridges and Buildings. T. Kennard Thomson (Visitor).
May	22.	Adjourned Meeting for discussion of Amendments to By-Laws.
May	25.	Adjourned Meeting for discussion of Amendments to By-Laws.
June	5.	"The Industrial Progress of Mexico." John Birkinbine (Active Member).
		"A Trail, Through the Mountains of Oaxaca Mexico." Henry E. Birkinbine (Junior Member).
September	18.	"The Sub-structure of the Passyunk Avenue Bridge, Philadelphia." Henry H. Quimby (Active Member).
October	2.	"The Testing of Sheet Steel for Magnetic Circuits." H. Clyde Snook (Active Member).
October	16.	"The Mulberry Street Viaduct at Harrisburg, Pa." John E. Allen and Benjamin G. Love (Active Members).
November	6.	"A Few of the Engineering Problems Involved in the Design of the Aeroplane." A. M. Herring (Visitor).
November	20.	"The Rating of Pitot Tubes for Use in the Test of a Niagara Power Plant." H. C. Berry (Active Member).
December	4.	"Diamond Mining." Henry Leffmann (Active Member).
December	18.	"Government Investigations and Tests of Fuels." Herbert M. Wilson (Visitor).

On the afternoon of May 1st a small party of Club members and guests made an inspection of the Torresdale Filter Plant, accompanied by Mr. Fred. C. Dunlap, Chief Engineer. This trip was arranged as a preliminary to the

paper of the evening, on "The Sanitary Control of Filter Plants," by Mr. F. D. West, chemist in charge of the plant, but the attendance was affected by very unfavorable weather conditions.

A reception, held April 30th, for the purpose of giving the ladies an opportunity of inspecting the Club-house, was attended by over three hundred members and guests; and a very successful vaudeville smoker, on November 12th, had an attendance of about two hundred and thirty. The expense of both functions was met by subscriptions from the members of the Club, and a small balance in the reception account was turned into the general fund of the Club. The smoker account also showed a small credit balance, but this was used to defray expenses of the Club nights, held the latter part of the year.

The Junior Section held eight meetings, at which the maximum attendance was thirty-one and the average twenty-one; or exactly the same as the average attendance of the seven meetings held last year.

The following papers were presented before the Junior Section:

January	16.	"The Organization of the Bureau of Surveys, Philadelphia."	E. J. Dauner.
February	15.	"Concrete Construction."	L. R. Ferguson.
March	15.	"The Development of the Water Turbine."	F. H. Rogers.
May	10.	"Building a Brick Gas Holder Tank."	Alfred Weeks (Visitor).
June	14.	"Manufacture of Portland Cement."	Richard L. Humphrey (Active Member).
October	11.	"Making and Placing of Concrete Piling."	R. P. Raynsford (Visitor).
November	15.	"Development of the Locomotive."	Stanley G. Child (Active Member).
December	13.	"Relationship Existing Between Engineer and Employer or Client."	John W. Brassington (Visitor).

In addition to the presentation of papers, the current numbers of the principal technical papers are reviewed at the meetings of the Junior Section. The section has a regular Committee on Inspection, and the list of trips follows:

March	6.	Pencoyd.
April	30.	Delaware Avenue Power Plant of the Philadelphia Rapid Transit Company.
June	12.	Penn Allen Portland Cement Plant.
November	20.	Victor Talking Machine Company's Plant, Camden, N. J.

On June 15th Mr. Redding, manager of the Club, resigned, and Mr. Mish, a non-member, was appointed to the position, which he retained until the first of December, when the House Committee decided to take over the management of the Club-house. On December 1st the House Committee cancelled the contract with the caterer for the operation of the restaurant and appointed a steward to take charge of the restaurant. The improvement in the service has been very marked, and it is believed that the change will be a decided benefit to the Club.

The lighting fixtures have been changed and the lighting rearranged so as to reduce the cost and increase the efficiency of the lighting.

Owing to lack of funds the library has not been improved as much as is desirable, the only money expended being that for the binding of periodicals. It is expected, however, that with the increased revenue available this year the condition of the library will be much improved.

The Publication Committee suggests that, in addition to the papers delivered before the Club, it would be desirable to secure original contributions from the members for publication in the "Proceedings." It is believed that such papers read by title at the meetings would considerably enhance the value of our publications.

Financial Report.

The following is the report of the accountants and auditors who have had charge of the books of the Club:

STATEMENT OF ASSETS AND LIABILITIES
as at December 31, 1909.

ASSETS.

Cash, Colonial Trust Co., active account	$1,319.00	
" Colonial Trust Co., interest account	1,736.61	
" In office	132.98	
" H. E. Ehlers, Treasurer	82.92	
		$3,271.51
Accounts receivable—Members' Ledger		1,666.77
Inventory of Supplies on Hand:		
Wine	$188.89	
Cigars	64.84	
Coal-house (estimated)	25.00	
Restaurant—Provisions	87.50	
" Coal (estimated)	3.25	
		369.48
Property:		
Building 1317 Spruce Street	$65,850.59	
Furniture and fixtures, house	6,622.53	
Furniture and fixtures, restaurant	1,294.31	
Library	2,118.39	
		75,885.82
Insurance:		
Perpetual on Club-house	$1,782.00	
Unexpired on furniture	7.86	
		1,789.86
Sinking fund for bond redemption		3,010.14
Total Assets		$85,993.58

LIABILITIES.

Accounts payable		$2,703.37
Bills payable		4,000.00
First mortgage	$40,000.00	
Second mortgage bonds	30,000.00	
		70,000.00
Carried forward		$76,703.37

Brought forward		$76,703.37
Accrued interest, first mortgage	1,080.00	
Accrued interest, second mortage bonds	1,730.00	
		2,810.00
Reserve for bond redemption		3,120.14
Christmas fund		44.50
Surplus as of January 1, 1909	5,621.28	
Less loss for year as per statement of Income and Expenses	2,305.71	
		3,315.57
Total liabilities		$85,993.58

STATEMENT OF INCOME AND EXPENSE.

Year ending December 31, 1909.

Expenses.

Salaries and Wages:		
House salaries and wages	$3,321.39	
Secretary's office salaries and wages	808.40	
Treasurer's office salaries and wages	1,466.35	
Restaurant salaries and wages	316.42	
Total salaries and wages		$5,912.56
Expense:		
House expense	$1,344.88	
Secretary's office expense	267.38	
Treasurer's office expense	258.72	
Total expense		1,870.98
Publications:		
"Proceedings" publishing	$1,358.57	
Directory advertising	51.30	
Directory publishing	357.85	
Total publications		1,767.72
Miscellaneous:		
Gas and electric light	$1,426.10	
Telephones	136.14	
By-laws revision	72.75	
Club luncheons	459.50	
Meetings	514.57	
Membership Committee	130.18	
Reception Committee	301.41	
Pool subscription	77.50	
Smoker	234.30	
Billiards and pool repairs	62.88	
Taxes and water rent	945.75	
Insurance	140.16	
State tax on bonds	120.00	
Badges	99.00	
Reprints	43.25	
Total miscellaneous expense		4,763.49
Interest and Discount:		
Interest on first mortgage	$2,160.00	
Interest on second mortgage bonds	1,420.49	
Discount on notes	82.00	
		3,662.49
Carried forward		$17,977.24

Brought forward			$17,977.24
Club-house Business:			
Restaurant purchases		$6,095.04	
Restaurant supplies		73.38	
Restaurant equipment		6.08	
Restaurant fuel		19.05	
Restaurant laundry		14.80	
Restaurant renewals and breakages		96.77	
Wine purchases		756.20	
Cigar purchases		878.86	
		$7,940.18	
Deduct Inventory of December 31, 1909:			
Wines and liquors	$188.89		
Cigars	64.84		
Coal and wood, house	25.00		
Restaurant, provisions	87.50		
Restaurant, coal	3.25		
		369.48	
Total Club-house business			7,570.70
Depreciation:			
Furniture and fixtures, house		$341.75	
Furniture and fixtures, restaurant		58.67	
Adjustment of furniture and fixtures accounts, January 2, 1909		45.68	
Adjustment of accrued interest as of December 31, 1908		80.00	
			526.10
Total expenses year ending December 31, 1909			$26,074.04

INCOME.

Dues—Net			$12,764.70
Publications:			
Advertising directory		$768.00	
Advertising proceedings		447.17	
Sales, proceedings		49.50	
Total from Publications			1,264.67
Miscellaneous:			
Interest on deposits		$37.79	
Discount		.22	
Rent of meeting room		40.00	
Reception committee		318.00	
Rent of typewriter		2.50	
Pool subscription		119.50	
Credit for interest on perpetual insurance		89.16	
Badge sales		132.25	
Reprints		43.25	
Smoker contribution		228.50	
Total Miscellaneous Income			1,011.17
Club-house Business:			
Restaurant sales		$5,079.94	
Wine sales		699.25	
Cigar sales		1,052.10	
Billiards and pool		214.02	
Lodging		1,636.21	
Total Income from Club-house business			8,681.52
Carried forward			$23,722.06

Brought forward	$23,722 06
Suspense	46.27
Total Income Year Ending December 31, 1909	$23,768.33
Total Expenses	26,074.04
Loss Year Ending December 31, 1909	$2,305.71

Respectfully submitted,

H. E. Ehlers,
Treasurer.

The above report has been prepared by the accountants employed by the Club. The auditors have examined accounts taken at random, and believe that the report as set forth above is correct. The bank balances are correct.

W. B. Riegner,
C. H. Ott,
D. Robert Yarnall,
Auditors.

The following is the report of the Trustees of the Bond Redemption Fund:

January 8, 1910.

Second Annual Report of the Trustees of the Bond Redemption Fund, being a statement of business for the year 1909.

1909.		Receipts.		
January	12.	Balance	$307.11	
January	12.	Coupons	15.00	
January	30.	Initiation fees	110.00	
February	15.	Initiation fees	135.00	
March	23.	Initiation fees	150.00	
April	30.	Initiation fees	155.00	
April	30.	Coupons	25.00	
May	3.	Initiation fees	85.00	
May	3.	Coupons	5.00	
June	30.	Initiation fees	15.00	
October	13.	Initiation fees	75.00	
November	20.	Initiation fees	230.00	
December	15.	Initiation fees	35.00	
December	31.	Interest on deposit	3.04	
December	31.	Coupons due 1-1-10	172.50	
				$1,517.65

		Expenditures.		
January	12.	Bonds	$300.00	
January	12.	Accrued Interest	15.00	
April	23.	Bonds	500.00	
April	23.	Accrued Interest	32.74	
May	6.	Bonds	100.00	
May	6.	Accrued Interest	6.77	
June	12.	Box Rent	3.00	
				957.51
		Balance		$560.14

In hands of Trustees:

Bonds owned	$2,450.00
Bonds in escrow	1,000.00
	$3,450.00

Respectfully submitted,

HENRY LEFFMANN,
EDWIN F. SMITH,
EDGAR MARBURG, *Trustees.*

The Auditors have examined the Trustees' account and found it to be correct. The securities are in the possession of the Trustees and the balance is in bank.

W. B. RIEGNER,
C. H. OTT,
D. ROBERT YARNALL, *Auditors.*

Respectfully submitted by the Board of Directors,

W. P. DALLETT, *President.*
W. P. TAYLOR, *Secretary.*

ABSTRACT OF MINUTES OF THE CLUB.

Regular Meeting, January 4, 1910.—The meeting was called to order by the President at 8.35 P. M., with 88 members and visitors in attendance. The minutes of the Business Meeting of December 18th were approved as printed in abstract.

Mr. W. H. Fulweiler, Active Member, presented the paper of the evening, entitled, "The Destructive Effect of Motor Traffic on Road Surfaces, and Methods of Construction to Prevent It." Messrs. J. W. Hunter, T. H. Boorman, S. M. Swaab, Benjamin Franklin, C. P. Birkinbine, J. O. Clarke, J. C. Wilson, E. M. Nichols and others participated in the discussion.

The meeting adjourned at 10.30 P. M.

Business Meeting, January 15, 1910.—The meeting was called to order by the President at 8.35 P. M., with 119 members and visitors in attendance. The minutes of the regular meeting of January 5th were approved as printed in abstract.

Following the report of the Tellers, the President declared the following elected to membership: Active, Rodney D. Allen, R. Ruliph M. Carpenter, Irenee du-Pont, Henry E. Hayward, John E. Hubbell, Harold S. Pierce, and Ferdinand F. Waechter; Associate, Herbert B. Allen, Edwin Smith and George D. Van Sciver; Junior, Harry P. Hammond, Horace G. Hill, Jr., William J. Taggart, and J. Howard Van Sciver.

Mr. Earle B. Phelps, visitor, presented the paper of the evening, entitled "The Disinfection of Water and Sewage," which was discussed by Messrs. F. Herbert Snow, George S. Webster, G. E. Datesman, Henry Leffmann, M. R. Pugh, R. H. Klauder, P. A. Maignen, and Mr. Phelps. Upon motion of Mr. Easby a vote of thanks was extended to Mr. Phelps.

Following the paper of the evening, Mr. F. Herbert Snow read a paper entitled "The Unification and Federation of Engineers in Pennsylvania," the discussion of which, upon suggestion of Dr. Leffmann, was postponed to some regular Club meeting in the near future.

Upon motion, the meeting adjourned at 10.35 P. M.

Thirty-first Annual Meeting, February 5, 1910.—The meeting was called to order by President Dallett with 129 members and visitors in attendance. The minutes of the Business Meeting of January 15th were approved as printed in abstract.

The Secretary announced that at the last meeting of the Board of Directors Mr. James Christie had been elected First Vice-President to fill the vacancy created by the election of Mr. Easby to the Presidency; and that Mr. H. E. Ehlers had been elected Director to fill the place vacated by Mr. Christie.

The Secretary also announced the death of Mr. Thomas C. Craig, Active Member, elected December 1, 1907; died January 26, 1910.

The report of the Board of Directors was presented, and, after some discussion, was approved.

Following a report of the Tellers, the President declared the following elected to Active Membership: Nicholas W. Akimoff, John C. Auten, John L. Curtiss, Arthur H. Haigh, and Wm. A. Smethurst.

President Dallett, after relinquishing the chair to Vice-President Devereux, made an address on recent developments in engineering practice.

Following a report of the Tellers, the President declared the following elected as officers of the Club for 1910:

President, Wm. Easby, Jr.
Vice-President, Charles Hewitt.
Secretary, W. Purves Taylor.
Treasurer, E. J. Kerrick.
Directors, David Halstead,
J. A. Vogleson,
Percy H. Wilson,
F. K. Worley.

Mr. Dallett then relinquished the chair to President Easby, who made a short address.

Upon motion of Mr. Rondinella, the thanks of the Club were extended to the officers and tellers of the year 1909.

The meeting adjourned, upon motion, at 9.50 P. M.

Regular Meeting, February 19, 1910.—The meeting was called to order by President Easby, at 8.40 P. M., with 95 members and visitors in attendance. The minutes of the Annual Meeting of February 5th were approved as printed in abstract.

The President announced the resignation of Mr. George T. Gwilliam from the Board of Directors, tendered on account of Mr. Gwilliam's continued absence from the city.

Mr. Ernest A. Sterling, Active Member, presented the paper of the evening, entitled "Some Notes on Wood Preservation and Creosote Production Abroad," which was discussed by Messrs. W. C. Furber, C. W. Tiffany, R. G. Develin, S. M. Swaab, P. A. Maignen, W. B. Riegner, John Foley, E. M. Evans, Thomas G. Janvier, and others.

Upon motion, the meeting adjourned at 10.25 P. M.

Business Meeting, March 5, 1910.—The meeting was called to order by President Easby at 8.40 P. M., with 114 members and visitors in attendance. The minutes of the Regular Meeting of February 19th were approved as printed in abstract.

Following a report of the Tellers, the President declared the following elected to membership: Active, Gilbert E. Barker, Charles N. Butler, J. Grier Foresman, Raymond W. Welsh, George W. Whiteman; Associate, Alfred L. Hallstrom.

Mr. John C. Parker, Active Member, presented the paper of the evening, entitled "A Labor-Saving Corporation and a Profit-Sharing Corporation," which was discussed by Messrs. John C. Trautwine, Jr., Carl G. Barth, Wilfred Lewis, R. H. Klauder, E. S. Hutchinson, H. M. Chance, Lesley Ashburner, P. A. Maignen and others.

Upon motion, the meeting adjourned at 10.30 P. M.

REGULAR MEETING, March 19, 1910.—The meeting was called to order by President Easby at 8.40 P. M., with 112 members and visitors in attendance. The minutes of the Business Meeting of March 5th were approved as printed in abstract.

Mr. Simon Lake, Visitor, presented the paper of the evening, entitled "The Principles Involved in the Design, Construction, and Operation of Submarine Vessels," which was discussed by Messrs. S. G. Comfort, Carl Hering, S. M. Swaab, C. C. Willits, Wm. Easby, Jr., Richard Gilpin, John C. Trautwine, Jr., and others.

Upon motion of Mr. Comfort, a vote of thanks was extended to Mr. Lake for his interesting and instructive paper.

Upon motion, the meeting adjourned at 11 P. M.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

Regular Meeting, January 4, 1910.—Present: President Dallett, Vice-Presidents Devereux and Easby, Directors Clarke, Head, Quimby, Twining, Develin, Plack, Gwilliam, the Secretary, and the Treasurer.

The Treasurer presented a statement of the present financial condition of the Club, and also announced that the following had, in accordance with the By-Laws, been dropped from the Club for delinquency in payment of dues: H. W. Affleck, C. F. Chambers, L. P. Clark, F. F. Glenn, W. H. Greul, P. M. Guba, E. N. Johnson, W. W. Nichols, A. E. Paige, H. S. Parks, C. J. Reed, G. Edward Smith, H. P. White, and A. M. Williams.

The following resignations were read and accepted as of December 31, 1909. Active: N. Z. Ball, E. F. Bertolett, Richard L. Binder, Charles P. Bower, H. DeH. Bright, J. R. Buchanan, Wm. B. Cavin, Edwin Clark, Chas. C. Davis, Henry DeHuff, F. E. Dodge, J. Scott Fowler, Chas. B. Gamble, J. H. Gillingham, J. McD. Greene, Chas F. Knight, J. A. Lafore, John T. Loomis, H. H. Manship, George L. Martin, James S. Merritt, Chas. P. Mulherin, A. M. O'Brien, L. H. Rittenhouse, C. J. Steen, Lee R. Stewart, Ernest G. Turner, and Chas. E. Wolle.

Mr. E. M. Bassett, whose resignation was accepted December 18th, was, upon request, reinstated as an active member.

Upon the suggestion of the Trustees of the Bond Redemption Fund, paragraph second, Section C, of Rule I, was rescinded, and for this was substituted the following:

"The Trustees of the Bond Redemption Fund are authorized to advertise for the purchase of second mortgage bonds at such times and in such amounts as may seem to them desirable, provided that such advertisements shall not be made until the sum of at least $500.00 has accumulated; and also provided that in the event of two or more bidding the same low figure, the awards shall be made by lot among these."

It was also authorized that an advertisement for the purchase of bonds be inserted in the coming notice of the Club.

It was moved and carried that an Art Committee be appointed to devise ways and means for bettering the artistic appearance of the Club-house, and that they be given power to act, provided they do so without unauthorized expense to the Club. Mr. W. L. Plack, Chairman, and Mr. George T. Gwilliam were appointed as two of the five members of this Committee, the other three to be appointed at the next meeting of the Board, upon suggestion of Messrs. Plack and Gwilliam.

Upon motion of Mr. Twining, the Christmas Fund collected by the Committee on House on December 23d was officially authorized; and it was also ordered that the undistributed balance of this fund be carried over until next Christmas.

The meeting adjourned, to continue on Saturday, January 15, 1910.

Adjourned Regular Meeting, January 15, 1910.—Present: President Dallett, Vice-President Wm. Easby, Jr., Directors Clarke, Twining, Christie, Develin, Plack, Mebus, Wood, the Secretary, and the Treasurer.

The following resignations were accepted as of December 31, 1909. Active: John M. Hartman, J. Harvey Borton, Wayne B. Morrell, J. W. Ridpath, Walter C. Aucott, Chas. H. Thumlert, J. V. Stanford, Elmer E. Melick, and John S. Haug.

Mr. H. P. White, Active Member, and Charles F. Chambers, Junior Member, dropped on January 4, 1910, were, upon request, reinstated in membership.

Mr. Wm. Easby, Jr., in view of his approaching election to the Presidency, tendered his resignation as Vice-President of the Club, which was accepted as of February 5th.

Upon motion, Mr. James Christie was elected Vice-President to fill the place vacated by Mr. Easby, for a term expiring February, 1911.

Mr. H. E. Ehlers was then elected a member of the Board of Directors, to fill the place vacated by Mr. Christie, term expiring February, 1911; both elections to take effect February 5, 1910.

The Treasurer presented the statement of the accountants for the month of December, and also for the year of 1909, the annual statement showing a net loss of $2230.71.

It was ordered that the President and Treasurer be authorized to reduce the existing loan of $4000 from the Colonial Trust Company, to a $2000 loan for sixty days.

It was ordered that the incidental expenses of the Trustees of the Bond Redemption Fund be charged to the general expenses of the Club.

The report of the Executive Committee was approved and given to the Secretary for final revision, the revised report to be submitted to a special Committee, consisting of Wm. Easby, Jr., J. O. Clarke, H. E. Ehlers, and Charles F. Mebus.

Organization Meeting, February 7, 1910.—Present: President Easby, Vice-Presidents Christie and Hewitt, Directors Plack, Mebus, Hutchinson, Wood, Ehlers, Vogleson, Wilson, Halstead, and the Secretary in attendance.

The annual report of the Board of Directors, as revised by the special committee and printed, was officially approved.

It was ordered that the Art Committee, W. L. Plack, Chairman, George T. Gwilliam, and three other members to be appointed, be continued.

The President then appointed the following to serve as standing Committees for the ensuing year:

House: W. L. Plack, H. P. Cochrane, Percy H. Wilson, A. C. Wood, F. K. Worley.
Meetings: W. P. Taylor, Chas. Hewitt, A. C. Wood.
Membership: Chas. Hewitt, James Christie, Chas. F. Mebus.
Finance: James Christie, H. E. Ehlers, Henry Hess.
Publication: Chas. F. Mebus, R. G. Develin, J. A. Vogleson..
Library: H. P. Cochrane, Edw. S. Hutchinson, H. E. Ehlers.
Publicity: David Halstead, George T. Gwilliam, W. P. Taylor.
Advertising: H. E. Ehlers, E. J. Kerrick, R. G. Develin.

The following were then elected by the Board to serve as Tellers and Auditors:
Tellers: Edwin M. Evans, E. J. Dauner, Louis S. Bruner.
Alternate Tellers: Alan Corson, H. F. Sanville, L. R. Ferguson.
Auditors: W. B. Riegner, C. H. Ott, D. Robert Yarnall.

Owing to ill health, Mr. E. J. Kerrick tendered his resignation as Treasurer of the Club, which, upon motion, was accepted. Mr. J. A. Vogleson was then elected Treasurer of the Club, and Mr. E. J. Kerrick elected member of the Board of Directors, to fill the place vacated by Mr. Vogleson.

It was ordered that the Finance Committee prepare an estimate of annual expenses for the ensuing year, to serve as a basis of appropriations to the various special Committees at the next meeting of the Board.

The resignation of Mr. P. R. Foley, Associate Member, was read and accepted as of January 1, 1910, and an overpayment of $17.50 on his account was ordered refunded.

Mr. F. D. Howell, Jr., dropped for delinquency on July 8, 1909, having paid his delinquent account, was reinstated, and his resignation accepted as of July 1, 1909. An overpayment of $6.25 was ordered to be refunded.

Mr. L. P. Clark was reinstated an Associate member.

A letter from Company "B", relative to certain charges on the books of the Club, was ordered referred to the House Committee, to report at the next meeting of the Board.

The tentative draft of a "Code regulating engineering practice in Pennsylvania," as formulated by the Code Committee, was ordered to be sent to each member of the Board, and to be brought up for discussion at the regular meeting in February or March.

REGULAR MEETING, February 19, 1910.—Present: President Easby, Vice-President Christie, Directors Ehlers, Gwilliam, Mebus, Halstead, the Secretary, and the Treasurer.

The Treasurer presented the report of the accountants, which showed a profit in the Club account of $127.21 for the month of January.

Mr. Christie, Chairman of the Finance Committee, presented an estimate of expenses for the current year. Appropriations to the various Committees were, however, postponed until the following meeting of the Board.

A letter from the Trustees of the Bond Redemption Fund, relative to the bond owned by the Link Belt Engineering Company and held by the Trustees, was read and referred to the Finance Committee to report at the next meeting of the Board.

The Secretary announced that letters had been received from the various officers, auditors, and tellers elected at the last Board meeting, all accepting office.

Upon motion, the annual salary of the Secretary was fixed at $416, and the annual salary of the Treasurer at $130.

Upon recommendation of the Committee on Membership, Mr. John G. Hendrie was transferred from Associate to Active membership.

The resignation of Mr. George T. Gwilliam as Director of the Club was read and accepted, and it was ordered that the Secretary be instructed to express to Mr. Gwilliam the appreciation of the Board for his services rendered the Club. Upon motion, Mr. Gwilliam was transferred to non-resident membership, as of January 1, 1910.

REGULAR MEETING, March 19, 1910.—Present: President Easby, Vice-Presidents Christie, Hess, Hewitt, Directors Cochrane, Develin, Plack, Mebus, Halstead, Wilson, Worley, the Secretary, and the Treasurer.

Upon recommendation of the Finance Committee, the following method of handling the bonds transferred to the Club by Mr. J. M. Dodge for the Link Belt Engineering Company was approved:

"These bonds shall have the detached coupons reattached, and the funds collected as interest shall be repaid to the Club by the Trustees.

"These bonds, with their full complement of coupons, shall remain in the custody of the Trustees until such time as the Board of Managers of the Club, shall require them, but the Trustees shall be relieved of further duty in connection with said bonds.

"An account to represent these bonds shall be opened in the books of the Club, credit being given for their face value.

"From time to time, as members are created upon the nomination of Mr. Dodge or other authorized officials of the Link Belt Engineering Company, the initiation fees and dues of such members shall be charged against the bonds and semi-annually thereafter the periodic dues of said members shall be charged up to the time limit specified in the agreement between Mr. Dodge and the Club.

"When the charges against the bonds shall balance their value, the bonds shall be canceled, and Mr. Dodge or his representatives notified of the fact."

The method of handling the coupons attached to these bonds was left to the discretion of the Treasurer.

The Treasurer presented the report of the accountants, which showed a net profit for the month of February of $240.76.

Upon motion, an account of $12.25 against W. S. Reid and an account of $22.00 against the Wheeling Mold and Foundry Company were ordered charged off the books.

Upon recommendation of the Committee on Meetings, a special meeting on April 30th was sanctioned.

The Committee on House presented a report of its work to date, which contained recommendations for the improvement of the Club-house.

Upon motion of the Secretary, it was ordered that a Committee be appointed to devise ways and means for raising a permanent fund for the use of the Club.

Following a report of the Committee on House on the renting of the meeting-room, it was ordered that this renting be left in the future to the discretion of the Committee on House.

Mr. Percy H. Wilson presented a detailed report of the operation of the restaurant, and, following this report, it was ordered that the Treasurer be requested to look into ways and means for improving the system of office accounts.

The resignations of Messrs. J. W. Cregar and William Warr were read and accepted as of even date.

Upon motion of Mr. Mebus, Mr. S. M. Swaab was elected a member of the Board of Directors to fill the vacancy caused by the resignation of Mr. George T. Gwilliam, term expiring February, 1912.

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Edited by the Publication Committee

CONTENTS

PAPERS.

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OF

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OF PHILADELPHIA.

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PAPER NO. 1085.

RATING OF PITOT TUBES.

H. C. BERRY.
(Active Member.)

Read November 20, 1909.

THE measurement of the quantity of water passing into the penstocks of the Ontario Power Company was a problem to which the Pitot tube was especially adapted. The writer presents to the Club this paper describing the methods employed in rating the tubes used in that work.

The intake works of the Ontario Power Company, located on the Canadian side of the Niagara River near the beginning of the rapids, consist of a large forebay protected by a curtain wall extending about 4 ft. below the surface of the water, a screen-house 600 ft. long, an inner forebay, and a gate-house at the entrance to the 18 ft. conduit. This conduit, about 6000 ft. long, is located from 3 to 30 ft. below the surface of the ground. At the lower end is a large, open, regulating chamber with an overflow discharging into the gorge.

Six 9 ft. penstocks carry the water from the large conduit to the individual turbines. Short submerged tail-races carry it from the turbines into the gorge at the back of the power-house.

As may be seen from Figs. 1 and 2, there is no suitable place in the whole course of the water for the construction of a standard weir. When the plans for the efficiency tests of the turbines were being made, several methods of measuring the quantity of water were considered. One of the most unusual of the proposed schemes was to inject a standard saline solution at a measured rate near the headworks, and by analysis of samples taken from the tail-race to determine the dilution and thus the quantity. It was finally decided to use Pitot tubes at the entrance to the conduit in the gate-house, and to check the work with a second series of tubes in the tail-race behind

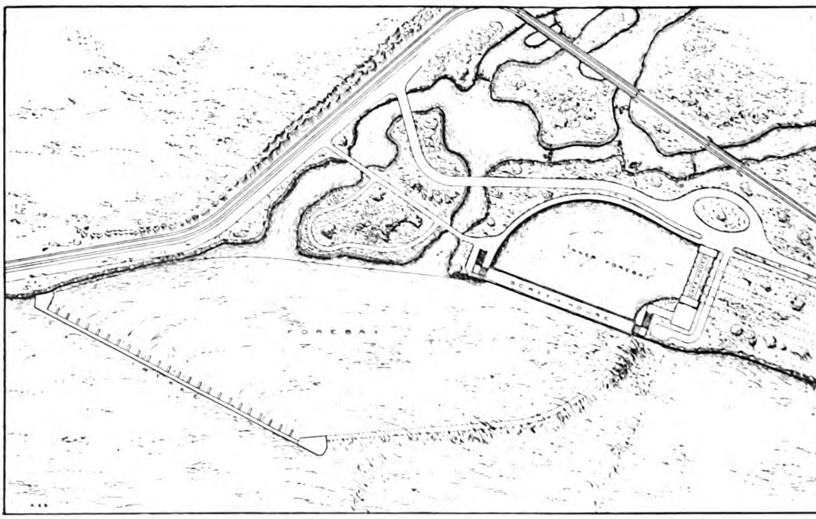


Fig. 1.—Plan of Ontario Power Company's intake works.

the power-house. Fig. 3 shows a section through the gate-house. The tubes were mounted on frames about 30 ft. long which could be moved up and down in guides shown at the first reduction of the channel. Five tubes were mounted on each of the six frames which were 5 ft. wide.

It is not the purpose of this paper to further describe the plant or to discuss the results of the test. This brief description has been given to show why the Pitot tube was used for this work and to present some conditions to which such tubes are especially adapted for the measurement of water.

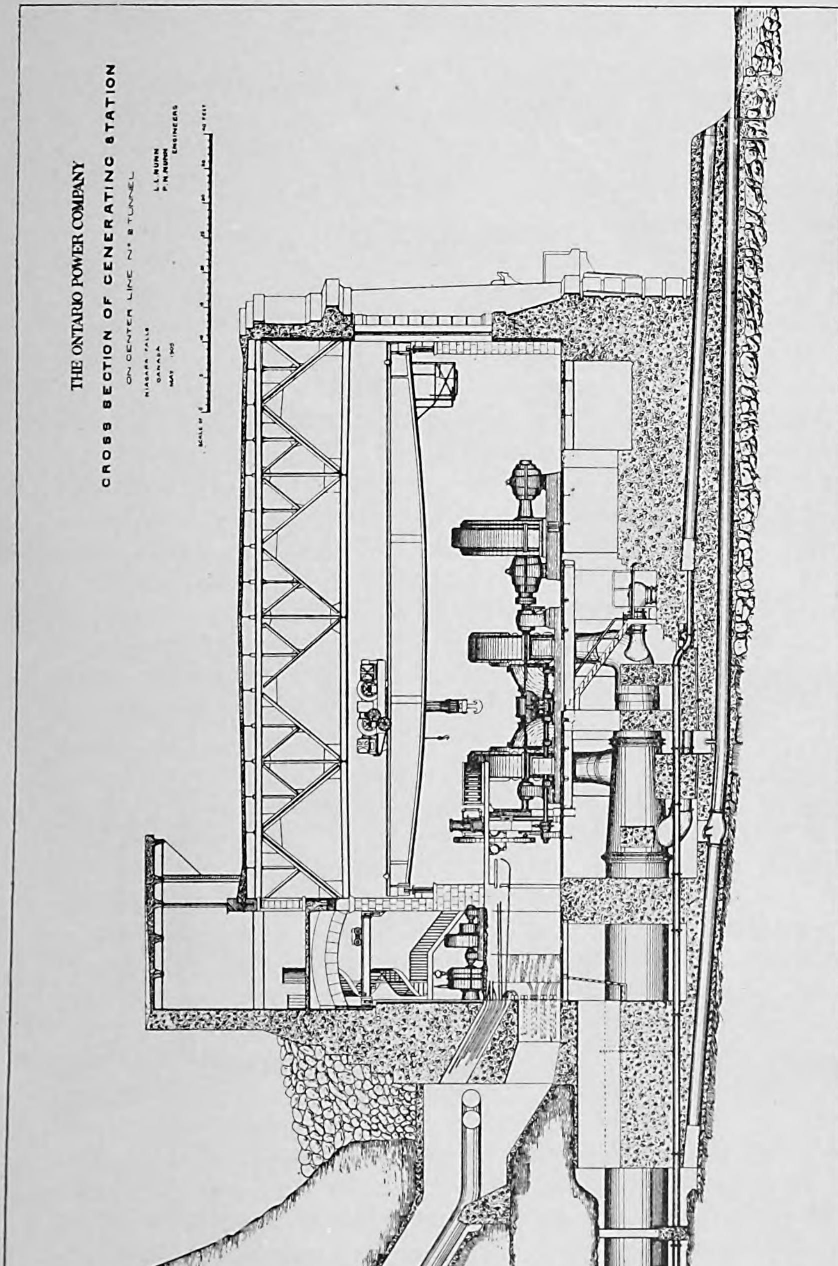

THE ONTARIO POWER COMPANY
CROSS SECTION OF GENERATING STATION
ON CENTER LINE No 2 TUNNEL
NIAGARA FALLS
CANADA
L. L. NUNN
P. N. NUNN
ENGINEERS

Fig. 2.

A Pitot tube is essentially a bent pipe of small diameter inserted in a moving fluid—water in this discussion—with its opening directed against the current. The impact of the water increases the pressure in the tube, lifts the water in it above the level of the stream a height

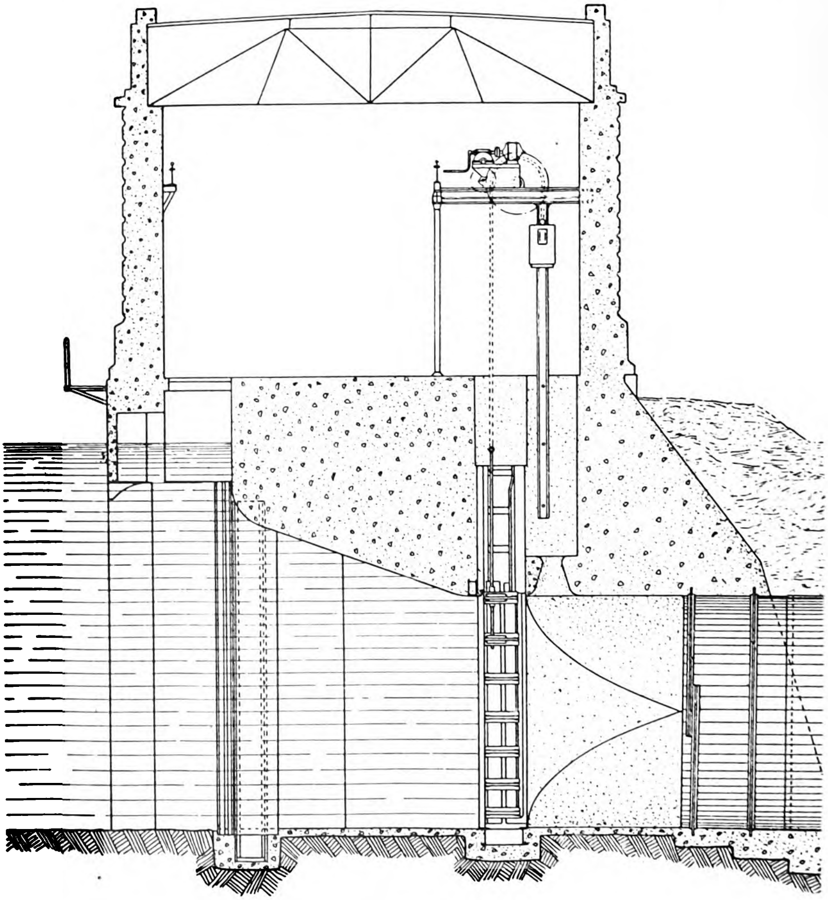


FIG. 3.—Section Through Gate-house.

h which theoretically is equivalent to the kinetic energy in the impact of that velocity equal to $\frac{v^2}{2g}$. This pressure may be indicated by a gage of the Bourdon type such as is used on standard apparatus for the measurement of fire streams, but it is more common to use for

this purpose a bent tube or differential gage partially filled with a suitable liquid. The latter type of gage requires two points of connection. When the tube is used in a closed pipe, one column of the gage is connected to the tube, and the other to an opening in the pipe, the "wall." A "wall" connection cannot be made in an open channel; hence, a second tube, to which the gage is connected, is inserted in the water with its opening pointed in a different direction from the first. Each is connected to a column of the gage. The two tubes inserted in the water are generally built together and are called a Pitot tube. The difference in height of the columns of liquid in the gage for any particular velocity and any particular tube is called the "head" for that tube and that velocity. Depending somewhat on the form of the "front," and more on the "back" opening, this "head" will vary for different tubes when in a stream of the same velocity, hence the necessity of rating such tubes before using them to measure the velocity of a stream of water.

The design of the tubes and special apparatus for the test of the Ontario Power Company's plant was in charge of Mr. J. C. Parker, assistant to Mr. O. B. Suhr, Construction Engineer. He was assisted by R. C. Carpenter, Professor of Experimental Engineering of Cornell University and Consulting Engineer to the Ontario Power Company. After considering the forms of tubes used by Professor Gardner S. Williams and his results as published in Vol. 47 A.S.C.E. Proceedings, they decided to use a symmetrical tube with a conical opening "front" and "back." A sample tube was made and sent to Professor Carpenter for rating. This was done in open water by mounting the tube and gage on a frame supported by two row-boats which were pushed over a course 600 ft. long by a power launch. About 60 runs were made at velocities varying from 1.5 ft. per second to 8.5 ft. per second, which gave a coefficient varying from 0.88 to 0.94 and averaging 0.915. The tube was easily clogged by débris in the water, so the later tubes were made with a very small opening and sharp points "front" and "back." They were finished by hand to bring the openings in the center of the points.

Because of the time required for rating by boat, arrangements were made to use the equipment of the College of Civil Engineering of Cornell University and rate the tubes in a closed pipe. T. J. Rodhouse, Professor of Hydraulics in the University of Missouri, then a Fellow in the College of Civil Engineering at Cornell, was engaged with the writer to rate the tubes, some fifty in number,

which were to be used on the test. Unfortunately the tube used on the boat had to be altered slightly in order to insert it in the pipe, and the results of the work on the boat are not comparable with those obtained later. Some delays in the delivery of part of the tubes gave an opportunity for rating a few of them by more than one method.

The results of a rating may be reported in two ways, the more usual of which is by finding the value of the "coefficient." This is done by measuring the "head" h for a number of known velocities of the water impinging on the point of the tube. Since this "head" is a manifestation of the kinetic energy of the water acting on the tube, it may be taken without further demonstration that the relation between the "head" and velocity is an expression of the form

$$h=k\frac{v^2}{2g}$$

in which k is an experimental constant for the tube being rated.

The second method of reporting the rating is to show a curve for which the heads and velocities are the coördinates. The relation given above between h and v is represented by a straight line when plotted on logarithmic paper. If the head for any reason does not vary as the second power of the velocity, a curve is preferable to a coefficient. If the rating is made in a pipe the first method is the more desirable, because the velocity of the water varies in different parts of the cross-section and the two variables cannot be directly observed, but must be compared by means of the above assumed relation. In this method any departure from the second degree relation between h and v will be shown by a slight variation in the value of k for different velocities.

In the study of the variations of the results of ratings of the tubes five methods were used, some of which were only slightly different in the conditions affecting the work.

The "pipe rating" consists in comparing the mean reduced velocities as observed by the tube at a series of points across the section of the pipe with the true mean velocity of the water in the pipe as determined from measurements by other standard means for determining the quantity. This ratio is called the coefficient, and the operation of taking the data "running a traverse" of the pipe.

By a "car rating" is meant observing the "head" on the gage and the velocity of the car on which the tube was mounted so as to project into still water beneath.

By "comparison in the pipe" is meant the simultaneous observation of the head on the gage of a tube to be rated and that of a standard tube, both being set at the middle of the same pipe carrying water at a velocity for which the standard tube is known to give accurate results. The comparisons should cover a wide range of velocities.

By an "open channel rating" is meant observing the "head" on the gage when the tube is inserted in a stream moving at a velocity determined by current meters.

By a "boom rating" is meant observing the "head" on the gage and the velocity with which the tube is moved in the water, when both are mounted on a boom turned at an observed rate.

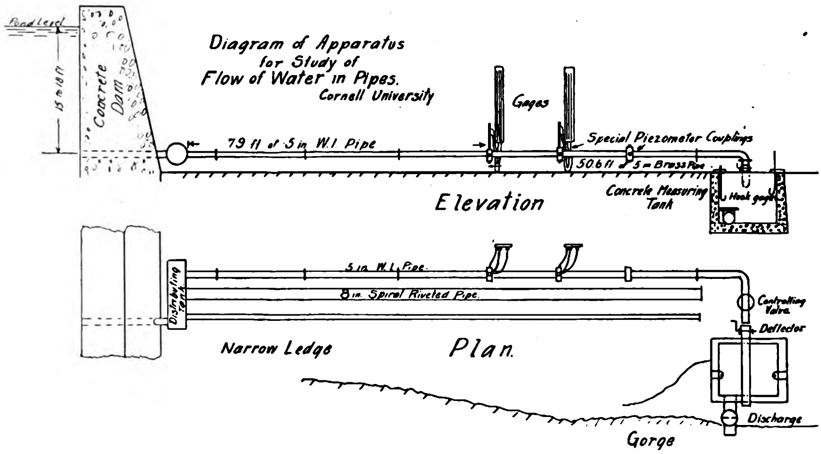


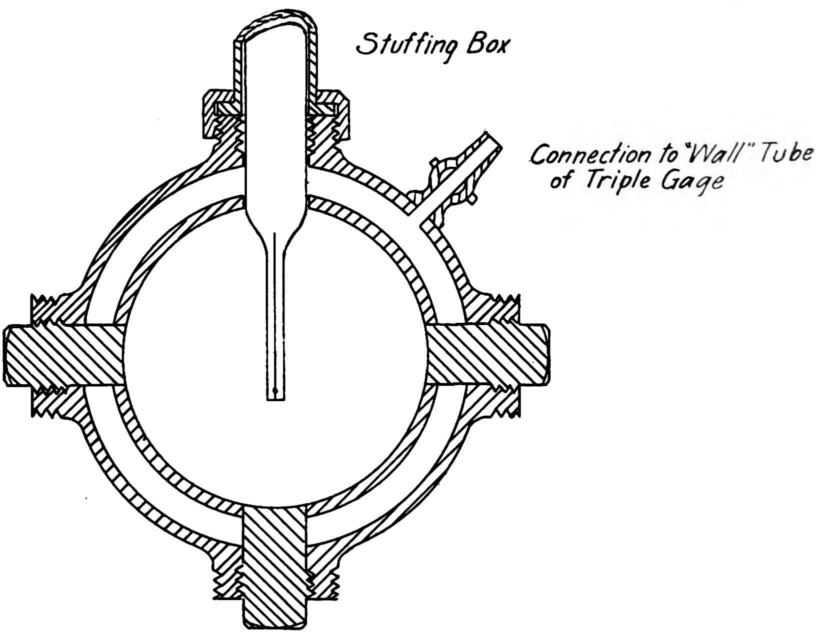
Fig. 4.

It is considered best to rate a tube under the same conditions, as nearly as they can be attained, as those in which the tube is to be used as a measuring apparatus. Since it was intended in the test of the Ontario plant to use the tubes in an open channel very near to the entrance to the conduit, it was considered that the conditions were nearly the same as in a pipe, and therefore it would be well to compare the ratings by the different methods for some of the tubes. For this comparison to be of any value it is necessary to describe the conditions under which the different ratings were made.

A diagrammatic outline of the apparatus used in the "pipe ratings" and in the "comparison in the pipe" ratings is shown in Fig. 4. It consisted of an opening through the dam connected to a small header

or distributing tank, of about 79 ft. of 5 in. wrought-iron flanged pipe, of 50.6 ft. of 5 in. seamless drawn brass tubing in four sections which were connected by special piezometer rings, of a regulating valve, a deflector, a measuring tank with hook gages and a large discharge valve, of differential gages, stuffing boxes for the tube, and of rubber connections.

The wrought-iron pipe had a mean diameter of 5.07 in., laid with just enough slope for drainage. The brass sections and rings were



Piezometer of "Ring" Type.

FIG. 5.

about 5.01 in. in diameter. The points where the tubes were used were more than 20 diameters below the beginning of the brass pipe and almost 100 diameters above the elbow and regulating valve at the discharge end. The conditions were excellent for undisturbed flow in the part of the pipe where the tubes were used, as is shown in the traverses plotted in Figs. 7 and 8.

The piezometer ring connection shown in Fig. 5 consisted essen-

tially of a hollow ring connected to the pipe by an annular opening about 0.01 in. wide. There were four 1 in. openings 90 degrees apart through which tubes could be inserted. The openings had plugs fitted to give a smooth interior to the pipe. The outside thread shown was for the attachment of the stuffing boxes of the tubes.

The stem of the tube fitting in the stuffing box was provided with a short pointer or indicator which was adjusted to the lowest "position" on the scale when the tube was set against the further side of the pipe. The point of the tube was thus located for setting on the 21 "positions" shown in Fig. 7. These "positions" were at the intersection of the diameter with the edges of 10 rings of equal area into which the cross-section is divided in order to lessen the labor of working up the observations.

Differential gages with three columns were used in all the work on this pipe. The details of these are the same as were used by Prof. G. S. Williams in his work at Detroit and described in Vol. 47 of the Proceedings A. S. C. E. The units on the scales were two centimeters long. The d. c. m. in the headings of some of the tables given later refer to this double centimeter unit. The air-cocks at the lower end of the columns were of great convenience in removing air-bubbles from the connections and in adjusting the height of the water in the gages before beginning a run. The gages used at Niagara were of essentially the same design but simpler in detail. The gages of all tubes mounted on one frame were connected at the top, and consequently under a common pressure. By this plan they could all be pumped at one time.

Three of the four forms of tubes used during the ratings are shown in Fig. 6. The fourth form was made on the same lines as the tubes used in the test, but the openings were conical, being about $\frac{1}{4}$ in. in diameter at the outer ends. The Williams tube "A" had been used in the Detroit experiments. Because of its sharp lines and narrow width it produced less disturbance in the water and less reduction of the area of the pipe than the other tubes. On this account it was taken as the standard in the "comparison in pipe" ratings. Its point was $\frac{3}{32}$ in. from the end, which prevented readings being made at "position" 21, the further side of the pipe. The openings were $\frac{1}{32}$ in. in diameter, that at the front as nearly on a knife edge as possible, and the two openings at the back were on the sides and so far back as to be on the curved surface.

The tube used in the test was a bronze casting 3 in. long, machined

to a sharp edge front and back. The openings were $\frac{1}{32}$ in. in diameter with the metal filed by hand to an edge of uniform thickness. The tubes were numbered with a steel die on the edge used as the "front" in all work. They were mounted by soldering $\frac{3}{8}$ brass tubing to the short nipples. The brass tube was connected to the gages by heavy rubber hose. This form of Pitot tube offered a relatively large obstruction to flow in the pipe and accordingly gave a more distorted figure when the traverses were plotted.

The Rodhouse tube was made in the field in order to see the effect of larger openings and of placing the back openings slightly further

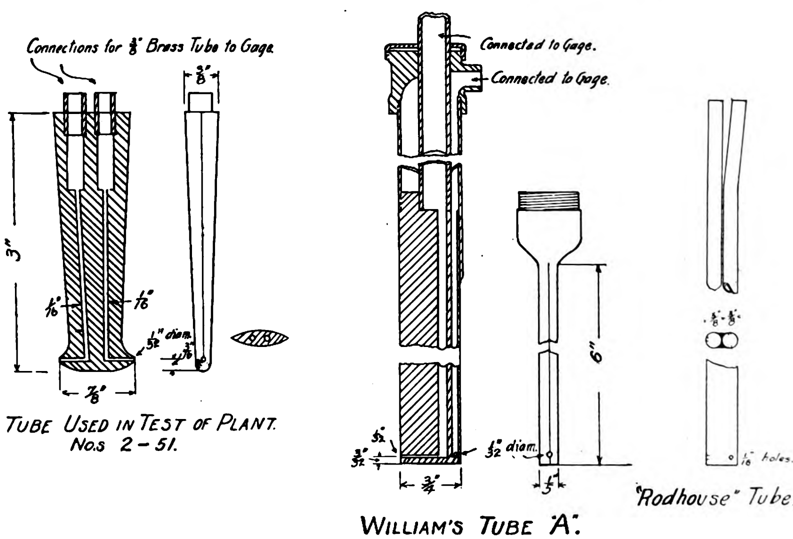


FIG. 6.

to the front than in Williams tube "A." It was made of two $\frac{3}{8}$ brass tubes plugged and soldered together with an excess of solder so as to make smooth sides. A $\frac{1}{16}$ in. hole was made in the front and two $\frac{1}{16}$ in. holes in the back tube. The latter were at right angles to the direction of the front opening. Its rating on the boom is shown in Fig. 17.

The operation of determining a value of the coefficient of a tube by "pipe rating" is called "running a traverse" of the pipe. This is usually done for several mean velocities, covering the range over which it is expected to use the tube. The method followed was to

divide the section of the pipe into ten concentric rings of equal area and make an observation with the point of the tube set on the division lines between the rings along the diameter traversed by the tube. The settings were made by use of the pointer and scale mentioned above. The mean velocity of the water in the pipe was determined by finding the quantity of water delivered in a measured time by use of the deflector and measuring tank.

The procedure followed in making a run was, first, to test the gage by noting if the water columns were the same height when the valve was closed or when the tube was withdrawn from the pipe into the stuffing box. If they were not, it was necessary to open the cocks to permit the water to flow through the gage and to manipulate the hose so as to drive out any entrained air. With the gage adjusted, the tube was thrust to the further side of the pipe and the pointer set on the divided scale to indicate the bottom, "position 21." The tube was then set at the center of the pipe and the regulating valve opened till the desired velocity was obtained. A reading on the three columns of the gage was then made. One of these was connected to the "front," one to the "back," and one to the "wall," so that h_t means the difference between the height of the column connected to the "front" and that connected to the "back," and h_w the difference between the column connected to the point of the tube and that to the "wall." After this center reading was taken a five-minute run was made at the tank for the volume flowing in that time. Then readings on the gages were made at "positions" 1 to C and another run of five minutes made at the tank. "Positions" 12 to 20 were then read and the tube again set at C, a reading made, and a third run made at the tank for quantity flowing in five minutes. The top of the columns vibrated considerably, depending on the velocity, so it was customary to make three readings on each column at each "position" and take the mean as the real height in making the reductions.

The notes were worked up in the field and the coefficient found by the following computations. H_t and h_w were found by taking the differences between the means of the readings of height of columns to "point" and "back," and "point" and "wall" respectively for each position. Then each head was reduced to velocity by the equation

$$v = \sqrt{2gh} \text{ which becomes } V = 2.05\sqrt{h}$$

for V in ft. per sec. and h in d.c.m. This required a single setting of the slide rule for each head. Since the readings were taken at the

sides of the rings into which the section was divided, the mean of the velocities at any two adjacent "positions" is the velocity to be used for the half ring between these "positions." Thus assuming the plot of the traverse to be divided into a series of trapezoids, we obtain the formula,

$$v_m = \frac{\frac{1}{2} V_1 + V_2 + \dots V_c + V_{12} \dots + V_{20} + \frac{1}{2} V_{21}}{20}$$

But since V_{21} cannot be observed and is assumed as the same as V_1, the above reduces to

$$v_m = \frac{V_1 + V_2 + V_3 + \dots V_{19} + V_{20}}{20}$$

The coefficient is then found from the relation

V_m × Area of pipe × Coef. = Volume of water per unit of time.

Fig. 7 is a plot of a traverse run with Williams' tube "A" showing also the division of the section of the pipe. The formula given above is an expression for the area bounded by the line of zero velocity, the

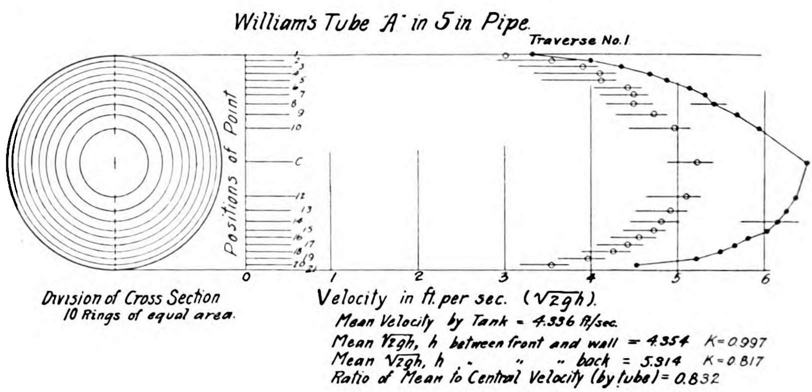


FIG. 7.

walls of the pipe, and the line connecting the plotted points. The above method of working up the data involves some approximations which may be most easily investigated by considering the plot:

(*a*) If the velocities at the "positions" vary as indicated, it is reasonable to assume that the values at points between lie on a smooth curve between these points. The above computation gives the area of the inclosed polygon in this curved surface, and hence is slightly smaller than the true area.

(*b*) The assumption that the velocity at position 21 is the same

as that at 1 is reasonable, but the traverses show a distortion on the side remote from that at which the tube is inserted, and if a smooth curve be drawn through positions 18, 19, and 20 and continued it will reach 21 at a considerably larger value than that at 1. From this cause the computed values of v_m are from 0.5 to 1.2 per cent. less than would be obtained if the symmetrical curve were used.

(*c*) A third source of error in the reduction of the data is in the assumption that the volume computed, the v_m times the area of the pipe, is the same as the volume of revolution generated by the rotation of the plot of the traverse. The amount of this error is roughly shown by taking an ellipse and 21 divisions; the difference obtained by the method used and the actual value of the ellipsoid of revolution is about 0.6 of 1 per cent.

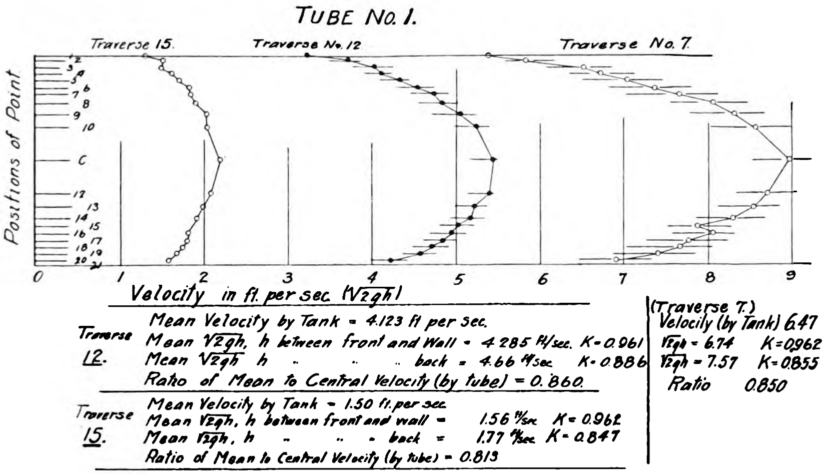


FIG. 8.

(*d*) If for any particular tube h does not vary exactly with the square of v, as is indicated in some of the results of the "boom rating," the method of reporting the rating of such tubes by means of a numerical coefficient to be applied to that relation will lead to error. In ratings made in a closed pipe a comparatively wide range of velocities is involved in running each traverse. All these are considered in computing the coefficient for that particular mean velocity, and consequently any effects due to a slight divergence from the second power of v being proportional to h would be obscured.

It was the practice of Professor Williams in the Detroit tests to modify the above formula by using the central velocity twice and dividing the sum by 21 instead of 20, as above. This was "to compensate for the deficiency occurring from the summation of the several velocities." This modification, if applied to the traverses shown, would increase the reported velocities very nearly 1 per cent.

WILLIAMS TUBE "A."

Traverse No. 1. Rating in 5 in. Brass Pipe.

Position.	H_w	H_p	V_w	V_p	U
	Double Centimeters.		Feet per Sec.		Mean Velocity by Tank.
C	6.50	10.08	....	....	4.335 ft. per sec.
1...........	2.18	2.60	3.02	3.31	..
2...........	2.97	3.73	3.54	3.97	..
3...........	3.55	4.46	3.87	4.34	..
4...........	3.96	5.14	4.09	4.65	..
5...........	3.09	5.55	4.10	4.84	..
6...........	4.62	6.20	4.42	5 11	..
7...........	4.74	6.61	4.47	5.28	..
8...........	4.73	6.89	4.47	5.39	..
9...........	5.30	7.60	4.73	5.66	..
10...........	5.81	8.30	4.96	5.92	..
C	6.48	9.96	5.22	6.47	4.336 ft. per sec.
12...........	6.10	9.60	5.07	6.36	..
13...........	5.75	9.21	4.92	6.24	..
14...........	5.44	8.91	4.79	6.13	..
15...........	5.28	8.56	4.71	6.01	..
16...........	4.88	7.95	4.54	5.79	..
17...........	4.61	7.60	4.44	5.66	..
18...........	4.30	7.13	4.26	5.48	..
19...........	3.70	6.37	3.95	5.18	..
20...........	2.98	4.78	3.54	4.49	..
21...........	Not observed	....	....	....	..
C	6.48	9.76	....	....	4.336 ft. per sec.
		Mean.....	4.354	5.314	4.336

Coefficient, Point and Back $= \frac{U}{V_p} = \frac{4.336}{5.314} = 0.816.$

Coefficient, Point and Wall $= \frac{U}{V_w} = \frac{4.336}{4.354} = 0.997.$

Ratio of Mean Velocity by Front and Back to the Central Velocity $= \frac{5.31}{6.47} = 0.82.$

TUBE No. 1.

Traverse No. 7. Rating in 5 in. Pipe.

Position.	H_w	H_p	V_w	V_p	U
	Double Centimeters.		Feet per Sec.		Mean Velocity by Tank.
C	11.44	14.34	....	....	..
1...........	4.44	5.39	4.88	5.37	..
2...........	5.22	6.30	5.28	5.81	..
3...........	6.74	8.17	6.02	6.52	..
4...........	7.17	8.44	6.20	6.72	..
5...........	7.74	9.27	6.44	7.03	..
6...........	8.49	9.36	6.75	7.36	..
7...........	8.93	10.88	6.93	7.64	..
8...........	9.34	12.17	7.08	8.06	..
9...........	9.84	12.85	7.26	8.30	..
10...........	10.54	13.73	7.52	8.56	..
C	11.52	14.76	7.86	8.93	..
12...........	10.86	14.08	7.65	8.70	..
13...........	10.63	13.65	7 56	8.56	..
14...........	10.09	12.80	7.35	8.28	..
15...........	9.07	11.44	6.96	7.84	..
16...........	9.71	12.08	7.21	8.06	..
17...........	8.69	11.24	6.83	7.77	..
18...........	8.29	10.92	6.68	7.66	..
19...........	7.68	10.21	6.42	7.40	..
20...........	6.67	8.82	5.90	6.88	..
21...........	Not observed	.....	....	....	..
C	11.41	15.07	....	....	6.47 ft. per sec.
		Mean.....	6.74	7.57	..

Coefficient, Point and Back $= \frac{U}{V_p} = \frac{6.47}{7.57} = 0.855.$

Coefficient, Point and Wall $= \frac{U}{V_p} = \frac{6.47}{6.74} = 0.962.$

Ratio of Mean Velocity by Front and Back to the Central Velocity $= \frac{7.57}{8.93} = 0.85.$

TUBE NO. 1.

Traverse No. 12. Rating in 5 in. Brass Pipe.

Position.	H_w	H_p	V_w	V_p	U
	Double Centimeters.		Feet per Sec.		Mean Velocity by Tank.
C	5.96	6.98	....	....	..
1..........	2.46	3.14	3.00	3.22	..
2..........	2.70	3.24	3.37	3.70	..
3..........	3.28	3.81	3.73	4.02	..
4..........	3.61	4.10	3.91	4.10	..
5..........	3.91	4.44	4.07	4.32	..
6..........	4.23	4.85	4.24	4.53	..
7..........	4.54	5.31	4.37	4.74	..
8..........	4.69	5.52	4.45	4.84	..
9..........	5.01	6.04	4.60	5.05	..
10..........	5.48	6.46	4.82	5.24	..
C	5.98	6.98	5.00	5.43	4.123 ft. per sec.
12..........	5.79	6.84	4.95	5.38	..
13..........	5.45	6.73	4.78	5.22	..
14..........	5.34	6.33	4.74	5.17	..
15..........	4.98	5.92	4.57	5.02	..
16..........	4.83	5.79	4.51	4.95	..
17..........	4.64	5.50	4.43	4.83	..
18..........	4.33	5.24	4.27	4.72	..
19..........	3.98	4.92	4.10	4.57	..
20..........	3.41	4.22	3.80	4.23	..
21..........	Not observed	....	....	....	..
		Mean	4.28	4.66	..

Coefficient, Front and Back $= \frac{U}{V_p} = \frac{4.12}{4.66} = 0.886.$

Coefficient, Front and Wall $= \frac{U}{V_w} = \frac{4.12}{4.28} = 0.961.$

Ratio of Mean Velocity to Central Velocity by Front and Back $= \frac{4.66}{5.43} = 0.86.$

TUBE No. 1.

Traverse No. 15. Rating in 5 in. Brass Pipe.

Position.	H_w	H_p	V_w	V_p	U Mean Velocity by Tank.
	Double Centimeters.		Feet per Sec.		
C	0.85	1.13	..	..	..
1	0.21	0.39	0.94	1.28	..
2	0.41	0.54	1.32	1.51	..
3	0.43	0.53	1.35	1.49	..
4	0.47	0.61	1.41	1.60	..
5	0.50	0.68	1.45	1.69	..
6	0.64	0.70	1.64	1.80	..
7	0.67	0.80	1.68	1.83	..
8	0.68	0.84	1.69	1.87	..
9	0.70	0.96	1.72	2.01	..
10	0.76	0.97	1.67	2.02	1.50 ft. per sec.
C	0.82	1.13	1.86	2.18	..
12	0.81	1.01	1.85	2.06	..
13	0.72	0.93	1.74	1.98	..
14	0.71	0.87	1.73	1.91	..
15	0.66	0.79	1.67	1.82	..
16	0.61	0.78	1.60	1.81	..
17	0.64	0.73	1.64	1.75	..
18	0.55	0.68	1.52	1.69	..
19	0.49	0.66	1.43	1.67	..
20	0.44	0.58	1.56	1.36	..
21	Not observed	..	..	..	..
		Mean.....	1.56	1.77	..

Coefficient, Front and Back $= \frac{U}{V_p} = \frac{1.50}{1.77} = 0.847.$

Coefficient, Front and Wall $= \frac{U}{V_w} = \frac{1.50}{1.56} = 0.961.$

Ratio of Mean Velocity by Front and Back to Central Velocity $= \frac{1.77}{2.18} = 0.813.$

RESULTS OF TRAVERSES.

Williams Tube "A."

Serial No. of Traverse.	Mean Velocity by Tank.	Coefficient.		Ratio of Mean to Central Velocity, both Observed by Front and Back.
		Front and Back.	Front and Wall.	
1.........	4.336	0.816	0.997	0.822
2.........	6.525	0.814	0.983	0.825
3.........	9.210	0.810	0.980	0.827
4.........	3.025	0.827	1.004	0.826
5.........	3.527	0.834	1.023	0.813
6.........	5.161	0.825	0.992	0.818
7.........	6.475	0.825	1.000	0.825
8.........	2.260	0.842	1.032	0.818
9.........	8.980	0.819	1.004	0.820
	Mean......	0.823	1.001	0.821

Tube No. 1. (Conical Openings.)

1.........	5.835	0.837	0.982	0.849
2.........	4.785	0.824	0.964	0.847
3.........	3.025	0.849	0.973	0.838
4.........	3.527	0.869	0.952	0.868
5.........	5.156	0.865	0.958	0.862
6.........	6.475	0.855	0.962	0.850
7.........	2.247	0.855	0.960	0.815
8.........	5.244	0.878	0.960	0.859
10.........	7.788	0.892	0.987	0.862
11.........	3.456	0.846	0.931	0.855
12.........	4.123	0.886	0.961	0.860
15.........	1.500	0.847	0.961	0.813
	Mean......	0.856	0.963	0.847

Tube No. 2. (Form Used on Test.)

1.........	6.28	0.889	1.008	0.840
2.........	3.35	0.901	1.000	0.845
3.........	5.23	0.880	1.000	0.862
	Mean......	0.890	1.003	0.849

Comparison in Pipe.

The method of "comparison ratings in the pipe" was adopted because of lack of time to run traverses covering a satisfactory range of velocities with each tube. It required an hour of rapid work to take the data of a traverse, and in event of trouble with air-bubbles this time was often doubled. Williams tube "A" was rated over a wide range of velocities; a sufficient number of traverses were run to determine quite accurately the value of the coefficient. It was therefore decided to place it and each of the other tubes in the center of the pipe and observe simultaneously the heads for a wide range of velocities. Since we had also determined a constant for the ratio of the velocity at the center to the mean velocity in the pipe, one point on each rating was checked by making a run at the tank for the mean velocity, to which the ratio was applied, and the central velocity found. This with the observed head gave one independent point on the rating curve. In making the comparison ratings ten readings were taken covering a range of velocities from about 1.5 to about 15 ft. per sec. The reduction of the data consisted only in finding the simultaneous heads on the two tubes and multiplying the coefficient of the Williams tube by the square root of the ratio of the head on it to that on the tube being rated.

$$K_t = K_w \sqrt{\frac{h_w}{h_t}}.$$

The results of the ratings by this method are given below for a few tubes only which were also rated by other methods in order to compare the values of k found by the different methods.

RATING BY "COMPARISON IN PIPE."

TUBE NO. 2. COMPARED WITH WILLIAMS TUBE "A."

READING NO.	SIMULTANEOUS HEADS. d. c. m. Tube A.	No. 2.	$\sqrt{\frac{H_A}{H_2}}$
1	20.30	15.80	1.135
2	14.60	11.60	1.12
3	8.65	6.80	1.128
4	5.40	4.22	1.134
5	2.60	2.47	1.035
6	14.48	11.38	1.13
(Mean velocity by tank for 6 was 5.187 ft. per sec.)			
7	19.64	15.83	1.115
8	6.50	5.33	1.102
9	3.10	2.62	1.087
10	13.00	10.50	1.112
(Mean velocity by tank for 10 was 6.11 ft. per sec.)			
			Mean 1.11

Coefficient Williams "A" = 0.825
Coefficient No. 2 = 0.825 × 1.11 = 0.915

TUBE NO. 5. COMPARED WITH WILLIAMS TUBE "A."

1	1.33	1.28	1.035
2	3.77	2.82	1.155
3	6.98	4.86	1.195
4	10.94	7.25	1.230
5	18.70	11.93	1.255
6	26.28	16.36	1.265
7	36.37	23.45	1.246
8	10.12	6.60	1.238
			Mean 1.202

Coefficient No. 5 = 0.825 × 1.202 = 0.996

TUBE NO. 6. COMPARED WITH WILLIAMS TUBE "A."

1	31.02	21.19	1.21
2	25.40	17.93	1.21
3	18.76	12.90	1.20
4	11.53	8.25	1.18
5	1.20	1.13	1.03
6	3.89	3.06	1.13
7	30.57	20.88	1.21
8	10.82	7.84	1.18
			Mean 1.17

Coefficient No. 6 = 0.825 × 1.17 = 0.966

TUBE NO. 7. COMPARED WITH WILLIAMS TUBE "A."

READING No.	SIMULTANEOUS HEADS. d. c. m. Tube A.	No. 7.	$\sqrt{\frac{H_A}{H_7}}$
1	37.85	23.40	1.272
2	32.86	20.49	1.268
3	26.67	16.77	1.266
4	18.88	11.86	1.262
5	11.57	7.50	1.240
6	1.47	1.15	1.130
7	6.72	4.49	1.225
8	4.59	3.53	1.143
9	1.55	1.20	1.137
10	0.49	0.45	1.042
			Mean 1.216

Coefficient of No. 7 = 0.825 × 1.216 = 1.003

TUBE NO. 8. COMPARED WITH WILLIAMS TUBE "A."

			$\sqrt{\frac{H_A}{H_8}}$
1	30.09	23.02	1.16
2	24.29	17.84	1.16
3	20.54	15.22	1.16
4	17.05	12.73	1.16
5	13.39	10.07	1.15
6	4.57	4.37	1.02
7	9.37	7.12	1.14
			Mean 1.14

Coefficient of No. 8 = 0.825 × 1.14 = 0.942

TUBE NO. 13. COMPARED WITH WILLIAMS TUBE "A."

			$\sqrt{\frac{H_A}{H_{13}}}$
1	8.37	6.21	1.16
2	15.21	11.00	1.18
3	22.63	16.20	1.18
4	31.00	22.31	1.18
5	35.08	25.03	1.18
6	1.71	1.41	1.10
7	3.98	3.10	1.135
8	7.65	5.70	1.16
9	11.55	8.50	1.165
			Mean 1.16

Coefficient of No. 13 = 0.825 × 1.16 = 0.956

Car Rating.

The experimental canal about 400 ft. long and 16 by 9 ft. in section was used in the "car ratings." The equipment included a car running on T rails, one on each side of the canal, with a wide platform on which the apparatus was mounted with the tubes inserted about 8 in. into the water. The car had a variable speed electric drive and an electric chronograph for the determination of the velocity. The operation of the tubes and the manipulation of the gages and connections differed from that followed in the work on the pipe only in that the gages were under a partial vacuum and had accordingly to be "pumped" to bring the columns up for observation. Leaks caused greater inconvenience than when working under pressure and were also more difficult to prevent. The initial adjustment of the gages was harder to obtain because the least leak that admitted air would throw the balance out and cause a difference in the heights of the columns when the apparatus was at rest. Any difference due to this cause continued to increase till the leak was stopped, and therefore it was not, as in the case of working with the gage under pressure, possible to make a correction for any initial difference in heights of the columns. The range of velocities obtainable with the car was from 0.7 to 5 ft. per sec. For the low velocities the momentary variations were large, and consequently the variations in the column readings varied greatly.

RATING BY USE OF CAR OVER STILL WATER.

Williams Tube "A."

Run No.	Velocity, Ft. per Sec.	Head. d. c. m.	Coefficient.
1	3.40	4.12	0.815
2	3.25	4.08	0.787
3	4.52	7.62	0.795
4	1.97	1.36	0.825
5	2.74	2.68	0.815
6	2.76	2.51	0.850
7	2.30	1.85	0.824
8	1.89	1.19	0.844
9	1.28	0.58	0.821
10	3.28	3.93	0.803
11	3.62	4.38	0.843
12	3.66	4.20	0.866
13	4.26	5.75	0.861
14	3.46	4.14	0.837
15	3.87	5.41	0.810
16	3.38	4.13	0.810
17	3.78	5.19	0.810
18	2.86	2.80	0.833
		Mean	0.825

Tube No. 1. (Conical Point and Back.)

		Head in Inches.	
1	3.73	3.54	0.862
2	3.46	2.80	0.891
3	4.18	4.35	0.865
4	4.10	4.50	0.836
5	2.58	1.58	0.887
		Mean	0.872

Tube No. 2.

1	2.80	1.53	0.978
2	2.40	1.11	0.985
3	1.87	0.76	0.925
4	1.33	0.39	0.908
5	3.22	2.15	0.946
6	3.54	2.42	0.980
7	3.59	2.67	0.970
8	3.66	2.72	0.958
		Mean	0.956

Tube No. 10.

1	3.67	2.51	1.000
2	4.38	3.46	1.013
3	2.60	2.67	0.975
4	3.14	3.21	0.976
5	3.77	2.70	0.990
		Mean	0.991

Open Channel Rating.

Some heavy rains that occurred while we were engaged on the work gave sufficient water to make a few observations with the tubes in the open channel of the experimental canal. The velocity of the water was measured with two Price current meters that we rated by means of the car one or two days before the run was made. The channel was 16 ft. wide and about 2 ft. deep. The velocity attained was about 2 ft. per sec. Though we were thus enabled to obtain but one point on a rating curve, it was thought worth while, in view of the conclusions reached by Professor Williams in his Detroit work, that the coefficients differed according to the conditions of rating.

The canal was lined with concrete, and consequently reasonably smooth; the tubes were set up about 200 ft. from the head-gates of the canal. There was about 10 ft. of rubber hose connecting the tubes to the gages, which were set about 6 ft. above the surface of the water.

RATING IN OPEN CHANNEL.

Williams Tube "A."

Run No.	Velocity by Meter.	Head. d. c. m.	Coefficient.	
1...........	1.530	0.74	0.865	Preliminary run.
2...........	1.875	1.25	0.820	
3...........	1.860	1.15	0.843	
4...........	1.890	1.23	0.830	
		Mean......	0.831	
Later.........	1.875	1.225	0.827	Mean of 11 readings.

Tube No. 1. (Conical Openings.)

Run No.	Velocity by Meter.	Head in Inches.	Coefficient.	
1...........	1.53	0.63	0.832	Preliminary run.
2...........	1.90	0.82	0.905	
3...........	1.90	0.80	0.917	
4...........	1.90	0.87	0.88	
		Mean......	0.858	

Tube No. 2.

Run No.	Velocity by Meter.	Head in Inches.	Coefficient.
1...........	1.46	0.48	0.952
2...........	1.86	0.78	0.906
3...........	1.78	0.80	0.858
		Mean......	0.906

Tube No. 5.

Run No.	Velocity by Meter.	Head in Inches.	Coefficient.
1...........	1.46	0.55	0.895
2...........	1.85	0.54	0.997
3...........	1.85	0.52	1.010
		Mean......	0.934

Boom Rating.

The arrangements for the test of the plant being incomplete when we reached Niagara Falls, we were enabled to rate all the tubes a second time by means of a rotating boom which Mr. Parker had provided for such a contingency. As shown in Fig. 8A, the apparatus consisted of a platform in the middle of which was a mast supporting a trussed 8″ x 8″ oak boom 25 ft. 1½ in. long from the center of rotation. It was balanced by bags of sand.

The rotating parts were so easily moved that one man was able to turn the boom, though generally two pushed and read the gages at

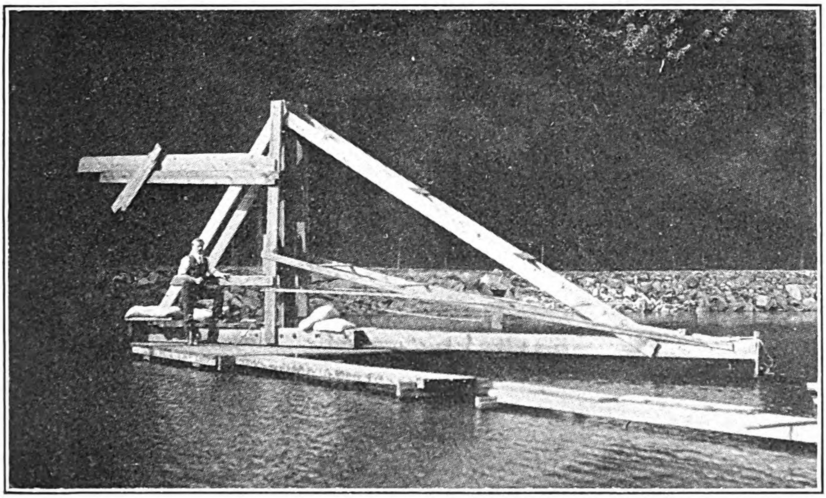


Fig. 8A.—Photograph of Boom used at Niagara.

the same time during a run. The gages were fastened to the mast and a seat arranged for the recorder.

Before rating a tube it was set vertical at the end of the boom, with a line through its point and back openings perpendicular to the boom. It was set about 16 in. deep, the water being about 3 ft. in depth at the shallowest place. At the highest velocity attained, the tube parted the water so as to make a depression behind it nearly 12 in. deep, but it did not expose the "back" opening. When the tube was set and connected to the gages, an air-pump was used to draw up the water and fill the gages to a convenient height for observation. This made a partial vacuum, about 6 ft. of water, in the gages, and conse-

quently we were troubled with all the inconveniences mentioned before in working under this condition. Glass tubing was finally used for the greater part of the connection from the tubes to the gage so that bubbles could be more readily detected.

In making a run two men read the gages and pushed the boom, regulating the force so as to maintain a constant head. The readings were taken as fast as the recorder could write them, and the average of all used as the head for that run. The velocity was observed by a fourth man, who took the exact time of rotation with a stop-watch. Runs at about ten different velocities were made with each tube, the range being from about 1.5 to about 15 ft. per sec. A low-velocity run was usually made at the beginning and close of a rating as a check on the constancy of the conditions at the gage.

While another tube was being adjusted on the apparatus the data were worked up and plotted in the field. This consisted in finding the average reading of each column for each run, taking the difference or "head," and in computing the velocity from the time of revolution and the length of the path traversed by the tube.

These heads and velocities were plotted on logarithmic cross-section paper especially prepared for this work. The logarithmic unit of the vertical or "head" ordinates was made one-half the length of the unit for the horizontal of "velocity" ordinate. This made the slope of a line through the plotted points about 45 degrees, making favorable intersections for reading off values from the curve.

The Club was favored last year with a paper which treated very fully the question of the theory of logarithmic paper. It is sufficient here to explain that any equation of the form $y = m x^n$ will when plotted on logarithmic paper be represented by a straight line, as may be seen by taking the logarithm of the above expression on each side, giving:

$$\log y = \log m + n \log x.$$

If now we regard *log y* and *log x* as variables Y and X, we have:

$$Y = n X + \log m \text{ (a constant)},$$

which is the familiar form of the equation to a straight line with n the tangent of its angle, with the X axis and log m its intercept.

The equation representing the law between velocity and head on the gages in the use of Pitot tubes is:

$$V = K \sqrt{2gh}$$

and remembering that $\sqrt{2g}$ reduces to 2.32 when h is in inches and V in ft. per sec., the logarithm of the above becomes:

$$\log V = \log K + \log 2.32 + 1/2 \log h.$$

An examination of this equation in connection with any plotted point on one of the rating curves will make clear the following graphic method of determining the coefficient resulting from the particular observation which the point represents.

"Draw a line through the point with a slope of 2 on 1 to intersect the horizontal; measure with the dividers the distance from point of intersection to 2.32 on the axis; if the intersection is to the right of the point 2.32, apply this length at the left end of the log. unit; if to the left, apply it to the right end of the log. unit." Note that we have used the fact that the log of a quantity less than unity is negative.

BOOM RATING IN DUFFERIN CHANNEL.

WILLIAMS TUBE "A."

Velocity in Feet per Second	Head in Inches.
4.51	5.99
5.16	7.72
3.72	3.77
3.94	4.65
2.45	1.81
3.44	3.60
5.60	9.94
4.24	5.09
1.13	0.63
1.53	0.75
1.00	0.46
2.47	1.78
2.80	2.44
3.03	2.85
3.60	3.86
3.10	2.68
3.90	4.45
4.48	5.89
2.62	1.97
3.62	4.16
5.03	7.64
6.95	14.61

TUBE NO. 1.

2.26	1.08
3.78	3.03
4.87	5.08
5.76	6.73
6.92	9.95
7.18	10.75
7.94	13.45
6.41	8.51
3.58	2.62
8.82	16.23

STILL WATER RATING IN DUFFERIN CHANNEL.

Tube No. 3.

Velocity in Feet per Second.	Head in Inches.
1.38	0.34
1.88	0.66
2.49	1.14
1.49	0.46
1.18	0.26

Above with oil in gage. Reduced to water.

3.15	1.80
2.61	1.25
4.47	3.67
5.71	5.73
6.86	8.10
7.58	10.30
9.46	15.62

Tube No. 4.

2.66	1.27
4.64	3.83
6.28	6.83
7.70	9.78
7.88	10.37
3.51	2.16

Tube No. 5.

On Boom at Dufferin Channel.

Velocity in Feet per Second.	Head in Inches.
2.72	1.51
2.19	0.92
2.57	0.97
2.05	0.64
1.34	0.41
1.55	0.55
1.77	0.55
2.46	0.98
2.27	1.02
4.10	2.88
5.00	4.12
6.05	5.68
6.35	6.84
1.82	0.47
2.55	1.20
3.49	2.20
3.12	1.64
2.19	0.88

BOOM RATING AT CORNELL LABORATORY.

Tube No. 7.

Velocity in Feet per Second.	Head in Inches.
12.2	26.2
11.5	24.0
10.8	21.3
10.2	18.4
9.6	17.2
8.9	13.5
8.0	12.2
7.3	9.6
6.1	6.9
5.7	5.9
5.1	5.2
4.5	3.8
3.9	2.64
3.7	2.52
2.45	1.37
2.45	1.21
2.00	0.96

BOOM RATING IN DUFFERIN CHANNEL.

Tube No. 7.

2.89	1.55
4.15	3.20
5.40	5.65
6.57	8.03
7.66	10.86
9.38	16.49
2.17	0.90

Tube No. 8.

Velocity in Feet per Second.	Head in Inches.
3.22	2.13
3.98	3.19
4.34	3.80
5.53	5.47

Tube No. 13.

3.44	2.24
4.86	4.10
6.12	6.39
6.57	7.30
7.30	9.13
8.35	11.70
3.11	1.63
2.53	1.19
2.35	1.10
3.25	2.04
8.66	12.33
8.90	13.55
9.40	14.60
8.54	12.07
3.02	1.62
4.69	3.85
6.26	6.80

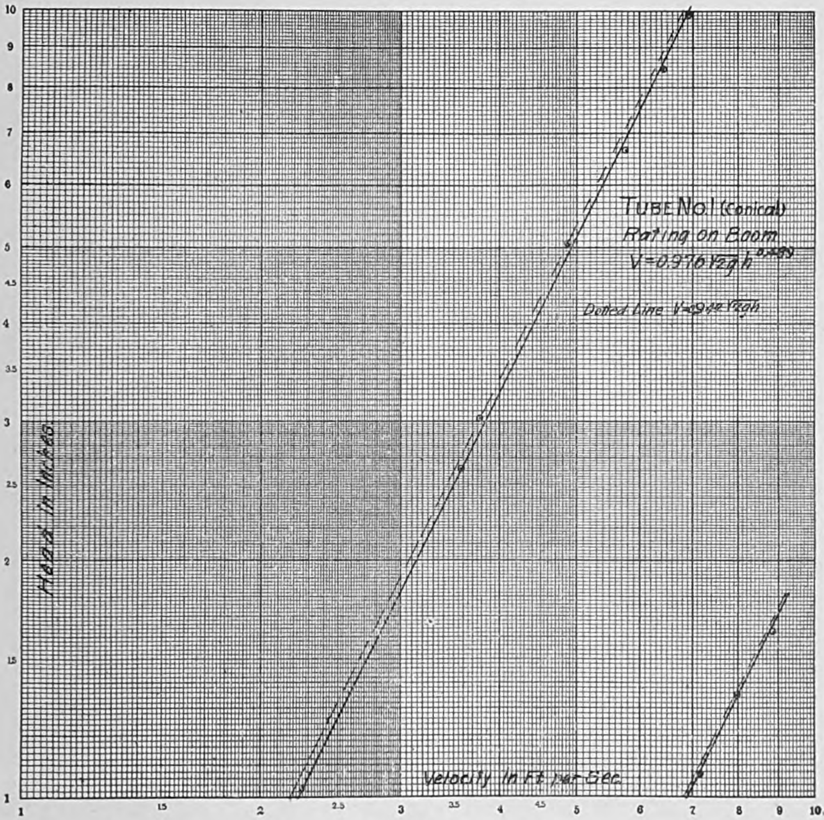

TUBE No 1 (Conical)
Rating on Boom
Dotted Line
Head in Inches
Velocity in Ft per Sec

Fig. 10.

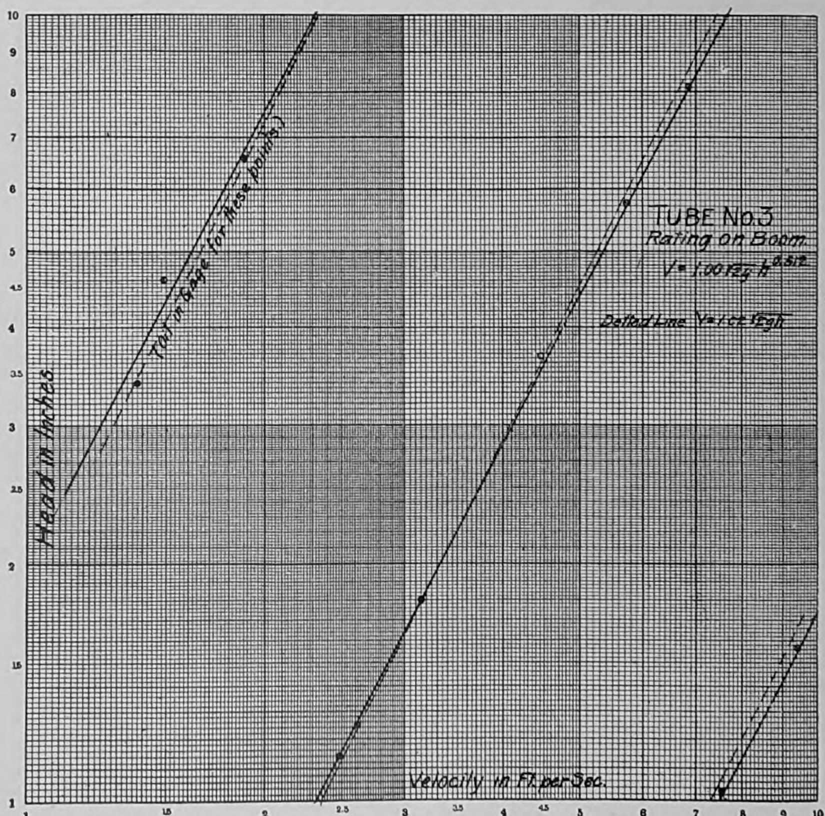

TUBE No.3
Rating on Boom
$V = 1.00\sqrt{2g}\,h^{0.512}$
Dotted Line $V = 1.00\sqrt{2gh}$
Head in Inches
Velocity in Ft. per Sec.
Tail in Gage (for these points)

FIG. 11.

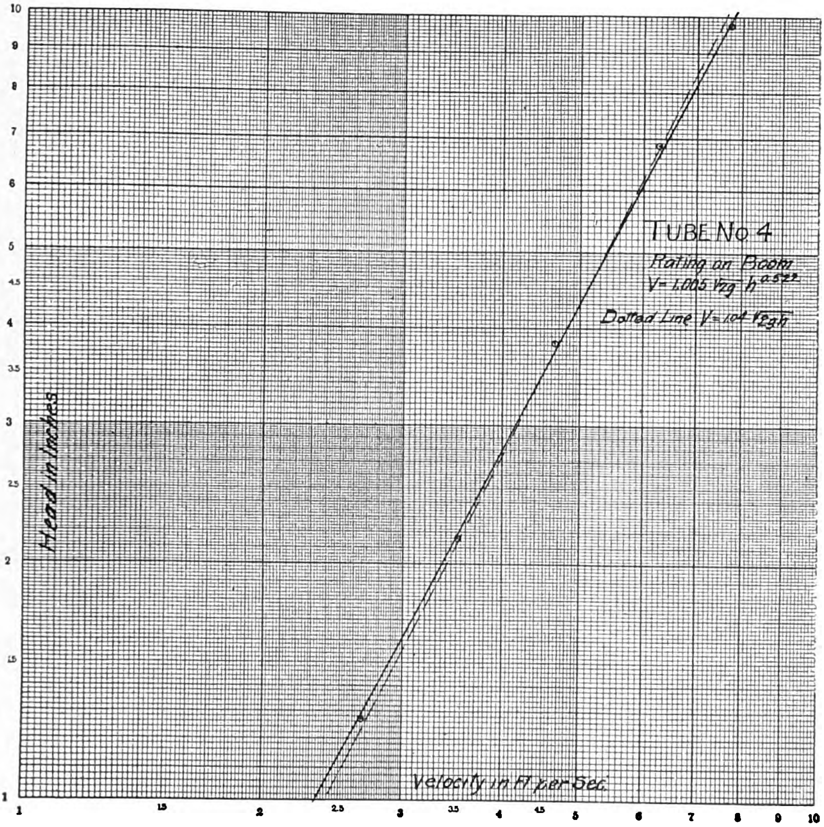
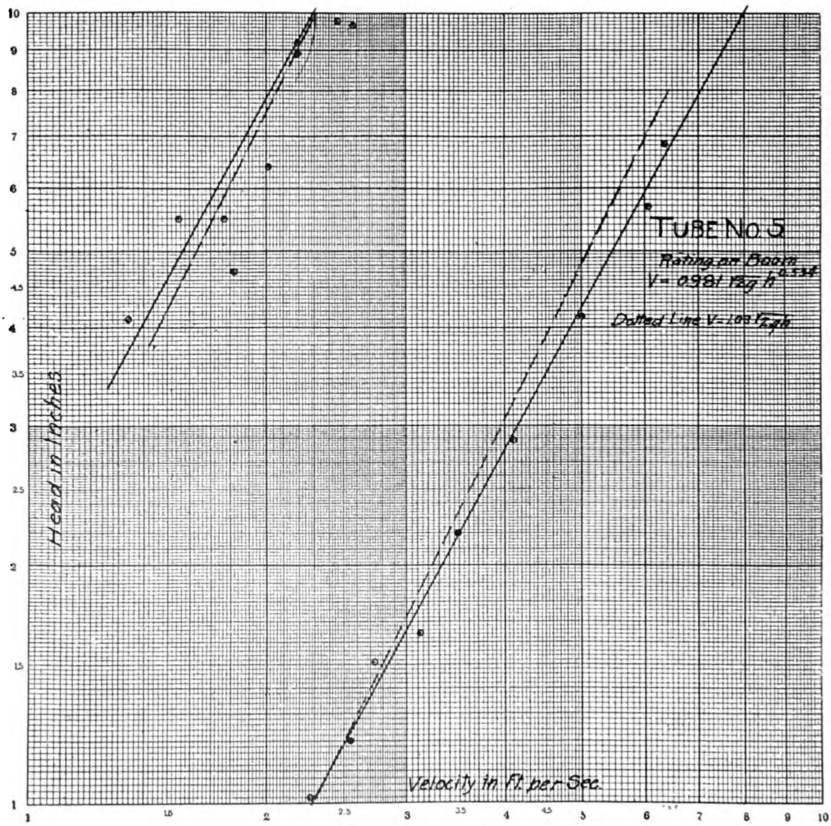

TUBE No 4
Rating on Boom
V= 1.005 √2g h^0.522
Dotted Line V= 1.04 √2gh
Head in Inches
Velocity in Ft per Sec.
10
9
8
7
6
5
4.5
4
3.5
3
2.5
2
1.5
1
1
1.5
2
2.5
3
3.5
4
4.5
5
6
7
8
9
10

FIG. 12.

3



TUBE No 5
Rating on Boom
V = .0981 √2g h^0.534
Dotted Line V = 1.03 √2gh
Head in Inches
Velocity in Ft. per Sec.
10
9
8
7
6
5
4.5
4
3.5
3
2.5
2
1.5
1
1
1.5
2
2.5
3
3.5
4
4.5
5
6
7
8
9
10

FIG. 13.

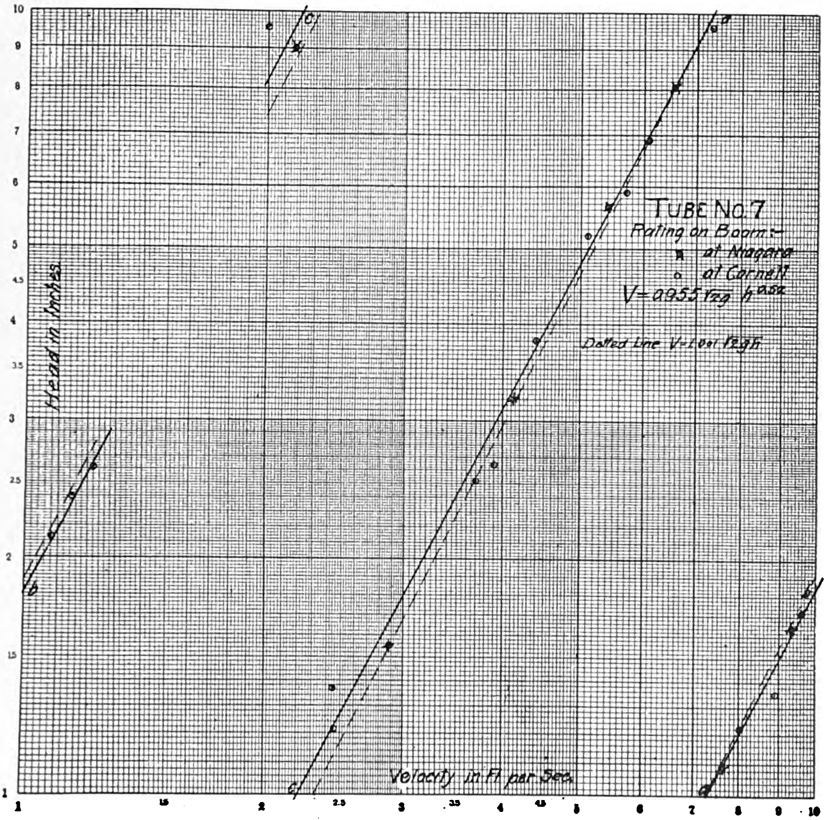
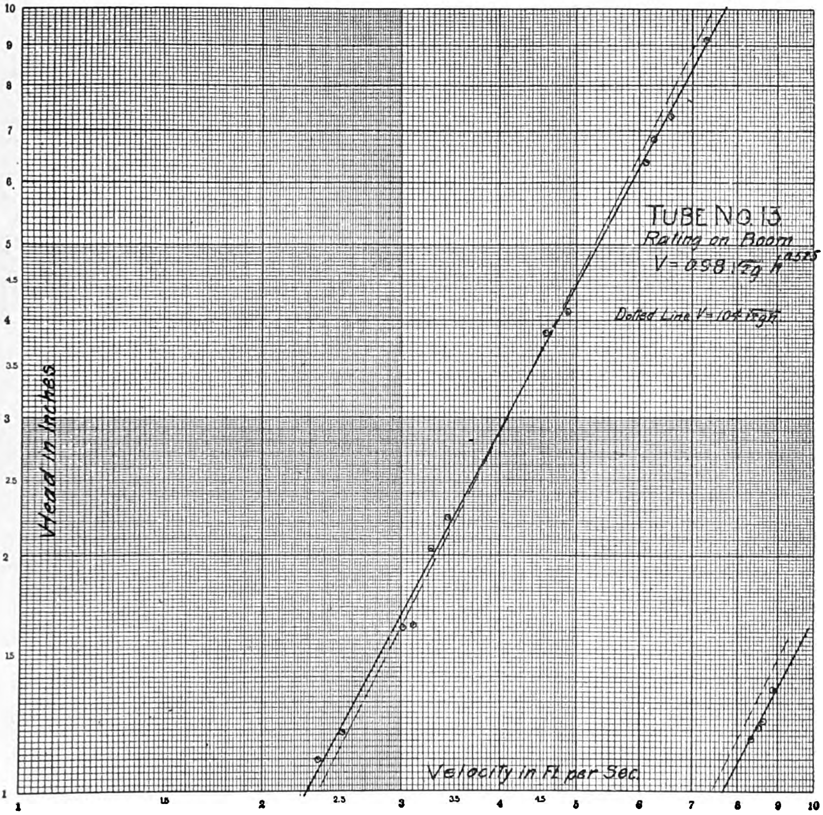

TUBE No. 7
Rating on Boom:—
at Niagara
at Cornell
Dotted Line
Head in Inches
Velocity in Ft. per Sec.

FIG. 14.



TUBE NO. 15
Rating on Boom
$V = 0.98\sqrt{2g}\,h^{0.525}$
Dotted Line $V = 1.04\sqrt{2gh}$
Head in Inches
Velocity in Ft. per Sec.
10
9
8
7
6
5
4.5
4
3.5
3
2.5
2
1.5
1
1
1.5
2
2.5
3
3.5
4
4.5
5
6
7
8
9
10

Fig. 16.

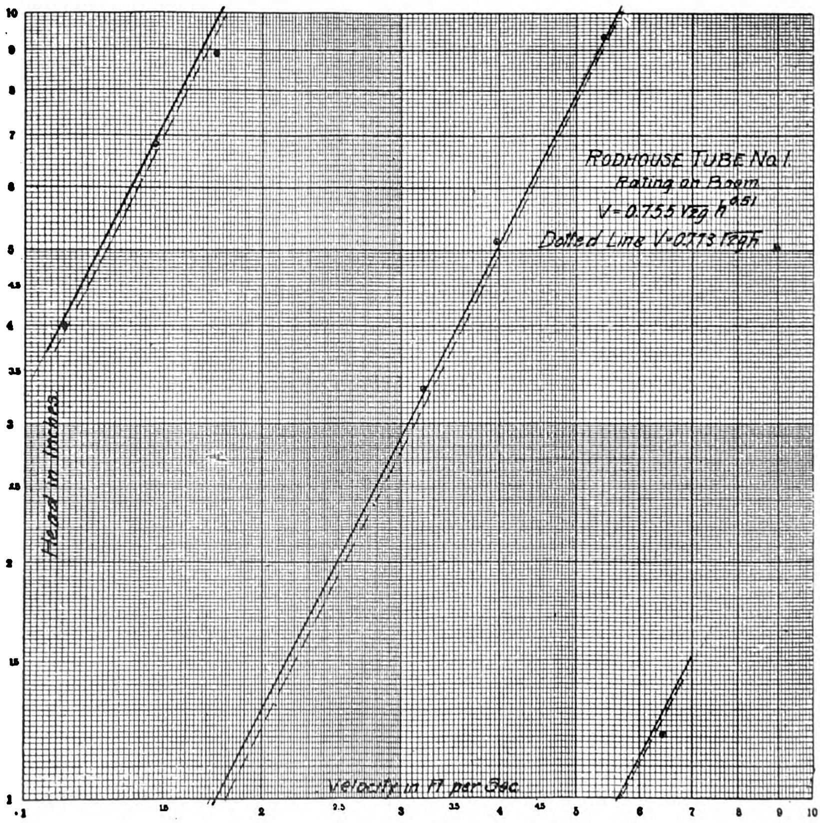

Rodhouse Tube No. 1.
Rating on Boom
V = 0.755 √2g h^0.51
Dotted Line V = 0.773 √2gh
Head in Inches
Velocity in Ft per Sec.
10
9
8
7
6
5
4.5
4
3.5
3
2.5
2
1.5
1
1
1.5
2
2.5
3
3.5
4
4.5
5
6
7
8
9
10

Fig. 17.

In Figs. 9 to 17 the values of *h* and *v* observed in the boom ratings are plotted on logarithmic cross-section paper. Most of the points lie reasonably close to the heavy line drawn to represent their mean position, and thus to express the relation between V and h with which the observations agreed. The dotted line shows the $\sqrt{2gh}$ multiplied by the coefficient obtained by taking the average of the coefficients for the different observations. This line is quite different for several of the tubes, and even for tube No. 7, which was rated by this method at two different places about a year apart, there is quite a divergence between the lines, though the work of the two observers checks very closely. This would indicate that taken over a wide range of velocity the coefficient of a tube may vary; in other words, the velocity may not vary exactly as the square root of the head observed on the gage. This difference is shown for several tubes in following table:

Tube.	Average Coef. in $V=k\sqrt{2gh}$.	Equation to Solid Line on Log. Paper.	Difference in Values of Velocity. At about 10 ft. per sec.	At 2 ft. per sec.
Williams A.......	0.786	$V=0.784\sqrt{2g}\,h^{0.50}$	Very small differences.	
Rodhouse No. 1...	0.773	$V=0.755\sqrt{2g}\,h^{0.51}$	0.16=1.5%	0.05=2½%
No. 1 con.........	0.942	$V=.976\sqrt{2g}\,h^{0.489}$	0.1 =1.5	.06=3%
No. 3............	1.02	$V=1.00\sqrt{2g}\,h^{.512}$	0.2 =3%	.02=1%
No. 4............	1.04	$V=1.00\sqrt{2g}\,h^{.522}$	—0.15=2%	+.08=4%
No. 5............	1.03	$V=.981\sqrt{2g}\,h^{.534}$	—0.5 =7%	+.04=2%
No. 7............	1.001	$V=0.955\sqrt{2g}\,h^{.520}$	0 =0	+.10=5%
No. 8............	0.969	$V=0.918\sqrt{2g}\,h^{.536}$	—3 =4%	+.10=5%
No. 13...........	1.04	$V=0.98\sqrt{2g}\,h^{.525}$	—3 =4%	+.08=4%

COMPARISON OF COEFFICIENTS AS OBTAINED BY THE DIFFERENT METHODS FOR THE SEVERAL TUBES FOR WHICH RATINGS ARE SHOWN.

Williams Tube "A."

Method of Rating.	Range of Velocity. Ft. per Sec.	No. of Ratings.	Value of Coefficient. Mean.	Highest.	Lowest.	Per Cent. Variation from Value by Boom.
Traverse.....	2.26— 8.98	9	0.823	0.842	0.810	+4.7
On Boom....	0.63—14.6	20	0.786	0.825	0.765	......
On Car......	1.28— 4.52	13	0.825	0.861	0.787	+5.
Open Ch'l...	1.86— 1.89	3	0.831	0.843	0.820	+5.7

Slight repairs had been made on the tube before the rating on the boom and after all the others had been made. It is possible, though not probable, that this may account for the wide variation.

In the computation of the coefficients of the other tubes by comparison in the 5 in. pipe the coefficient of Williams Tube "A" was taken as 0.825.

TUBE NO. 1. (CONICAL POINT.)

METHOD OF RATING.	RANGE OF VELOCITY. FT. PER SEC.	NO. OF RATINGS.	VALUE OF COEFFICIENT.			PER CENT. VARIATION FROM VALUE BY BOOM.
			Mean.	Highest.	Lowest.	
Boom.......	2.26—8.82	10	0.942	0.956	0.925	......
Traverse.....	1.5 —7.78	13	0.86	0.892	0.824	—8.7%
On Car......	2.58—4.18	5	0.872	0.891	0.836	—7.5
Open Ch'l....	1.90	3	0.900	0.917	0.880	—4.5
Comparison .	....	4	0.90	.....	.....	—4.5
TUBE NO. 2.						
On Boom....	Data not in my notes.					
Traverse.....	3.35—6.28	3	0.890	.901	0.880	
On Car......	1.87—3.59	8	0.956	0.985	0.925	Boom
Open Ch'l...	1.86	1	0.906	.....	.....	data
....	2.07	1	0.86	.....	.....	missing
Comparison..	....	...	0.915	.....	.....	
TUBE NO. 3.						
Boom.......	1.38—9.46	11	1.02	1.045	1.00	......
Comparison..	....	8	0.956	0.998	0.892	—5.9
TUBE NO. 4.						
Boom.......	....	6	1.04	1.05	1.01	....
Comparison..	....	9	1.035	1.07	0.932	—4
TUBE NO. 5.						
Boom.......	1.34—6.35	9	1.034	1.09	0.98	......
Open Ch'l...	1.85 1.66	2	1.02	1.06	0.99	1
Comparison..	....	...	0.99	1.04	0.85	—4
TUBE NO. 7.						
Boom:						
at Niagara	....	7	1.01	1.035	0.995	......
at Cornell..	....	15	1.001	1.03	0.970	—1
Comparison..	....	9	1.003	.....	.....	—0.3
TUBE NO. 8.						
Boom.......	....	4	0.969	1.01	0.95	......
Comparison..	....	...	0.942	.....	.....	—2.8%
TUBE NO. 13.						
Boom.......	....	9	0.963	0.99	0.95	......
Comparison..	....	...	0.956	.....	.....	—0.7%

It is evident that for some of the tubes the use of an average coefficient applied to $\sqrt{2gh}$ may give a value of V differing by from

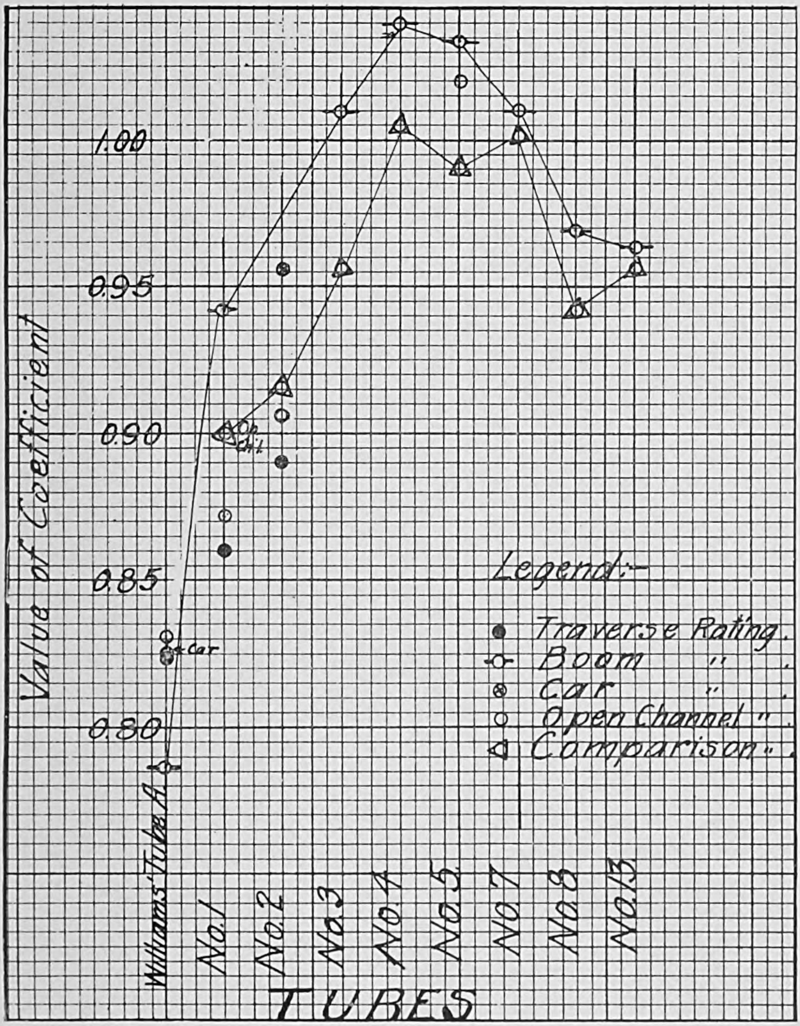


Fig. 18.

2 to 7 per cent. from the real value as obtained by use of the true curve.

Something of this difference is shown in the variation of the value

of the coefficient obtained in traversing if the values for widely different velocities are compared. Any difference, however, is clouded because of the wide range of velocities observed in the cross-section of the pipe, and because of the use of the assumed relation in working up the results. By the boom rating, however, each observation in itself makes a complete determination of the coefficient, and if a curve is used to report the results of the rating no reductions are required in its determination.

Fig. 18 shows the values of the coefficients of the several tubes as obtained by different methods. This figure does not give proof of the opinion we had at one time during the work; *viz.*, that the coefficient of a tube is the same no matter what the method of rating, provided that the method is used so as to take into account such conditions as the present development of hydraulic knowledge makes possible. We had obtained for the Williams tube a coefficient of 0.823 by traversing, of 0.825 by use of the car, and 0.831 in a limited number of observations in an open channel in comparison with current meters. But when placed on the boom it gave 0.786 based on a number of observations part of which were made on different days. The first three coefficients warranted the use of 0.825 as the coefficient of Williams tube "A" for purposes of comparison with the other tubes in the 5-in. pipe. The values found by comparison are shown and connected by a broken line, as are those obtained on the boom. The two lines have much the same shape, the comparison values being smaller for all the tubes, but the difference is not the same for all. For No. 7 and No. 13 the values differ by 1 in the second decimal place, but for Nos. 1, 3, 4, 5, and 8, the difference is more nearly constant at about 4 in the second decimal place. Therefore we must conclude in consideration of the data here given that in so far as it indicates, it is necessary to rate a tube under as nearly as possible the same conditions as exist at the place where the tube is to be used as a measuring instrument, but that when so rated we may have confidence in its results to the usual requirement of 1 per cent. The work on the boom shows closer agreement in its results than does Williams tube "A" in the pipe. And we feel sure that the larger tubes would give more consistent results if rated in larger pipe, so as to cause less disturbance at the section where they are inserted.

DISCUSSION.

WM. EASBY, JR.—The Pitot tube bears the name of its inventor, a French engineer, who made measurements with it as early as 1750. His observations

were made in streams moving at low velocities, and the apparatus under those conditions did not give very satisfactory results. So far as can be ascertained very little use was made of this instrument until about 1850. Its satisfactory use for low velocities has been made possible by employing in connection with it a differential tube containing some liquid lighter than water for magnifying the tube deflection, thereby making the error in reading relatively smaller. For high velocities a water column may be directly read, and for very high velocities, as, for instance, in the experiments of Freeman in 1888, for determining the flow through nozzles, a liquid heavier than water is desirable.

A difference of opinion exists to-day regarding the accuracy of the Pitot tube, and the reason for this can be explained by the variation in the coefficients which have been obtained under the same experimenters, working presumably with equal care throughout their investigations.

Among the most careful series of readings are those which have been made in comparatively small cross-sections where the introduction of the tube itself has been without doubt a disturbing element. The same tubes introduced into much larger pipes would produce very much less disturbance, and it is reasonable to assume that if the calibration had been made in these pipes, the coefficients would have been different. The great value of the Pitot tube lies in its portability and its cheapness. It may be used where it would be expensive or impossible to construct weirs, or to install orifices. It is the only instrument which can be used in turbines and centrifugal pumps to obtain the velocities in the different parts.

I do not wish to give the impression that I underrate the value of the Pitot tube for obtaining discharges under the conditions mentioned. A large amount of experimental work has been done with the Pitot tube in an attempt to perfect it and the methods of its use, and there is little doubt that in the course of time the concordance of results will lead to greater confidence in its use.

John C. Trautwine, Jr.—I am especially glad to see Mr. White here this evening, inasmuch as, by a curious coincidence, I received this morning a letter from a correspondent in New Zealand, commenting upon the effect, upon the coefficient, of the suction opposite the lateral opening in a double Pitot tube.

Some ten years ago Mr. White published, in the Journal of the Association of Engineering Societies, a most illuminating paper entitled "The Pitot Tube; Its Formula," and I was sure that he could throw light upon this question of the disturbing effect which the lateral orifice has upon the coefficient.

As I understand Professors Berry and Easby, all such disturbing effects are taken care of in the coefficient, which, in their practice, is determined by rating the tube for each particular case; but, in view of the difficulty of such rating, in many cases, I think we must agree with Mr. White that it is desirable to select such an arrangement of orifices as will bring the coefficient very close to unity, thus eliminating these disturbing factors.

It may be of interest to mention that Professor Robinson has used the Pitot tube for measuring flow of air and gases, and that M. Bazin has used it for measuring the velocity in the thin sheet of water flowing over a weir, an application for which the Pitot tube is perhaps the only device that could be used.

William White.—About ten years ago I had occasion to test a centrifugal pump and to measure the flow of water in the 5-foot diameter discharge pipe of

the pump, by means of the Pitot tube. The velocity of the water in the discharge pipe varied from about 16 to 20 feet per second. A Pitot tube which belonged to

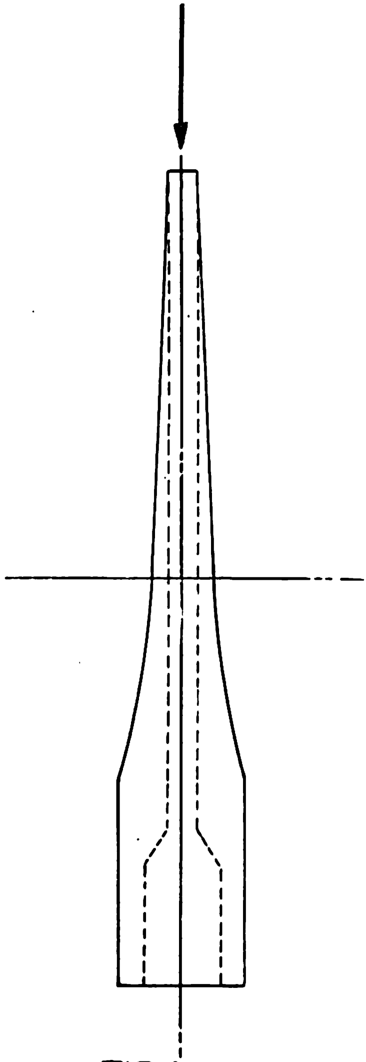


FIG. 1.

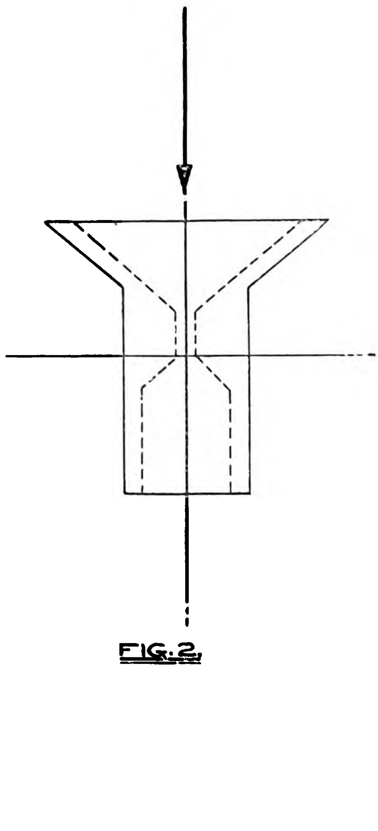


FIG. 2.

the Tulane University in New Orleans was used on this work, and the coefficient of the tube was given as 0.85.

At about the time of the test, there was a discussion in New York on Professor

Gregory's paper entitled "Water Measurements in Connection with a Test of a Centrifugal Pump at Jourdan Avenue Drainage Station," and in the course of the discussion Mr. Kent said that the correct formula for the Pitot tube is $V = \sqrt{gh}$. At the time I could not see how this formula could be true, so I went into the question at length to determine the correct formula and the coefficient of the tube.

Considerable difference of opinion exists among engineers to-day because of the fact that when engineers explain the theory and application of the tube they do not separate the point of the tube from the piezometer opening of the tube, but confuse your mind with a lot of coefficients. The point of the tube is the real Pitot tube, and has a coefficient of unity. This holds good no matter whether

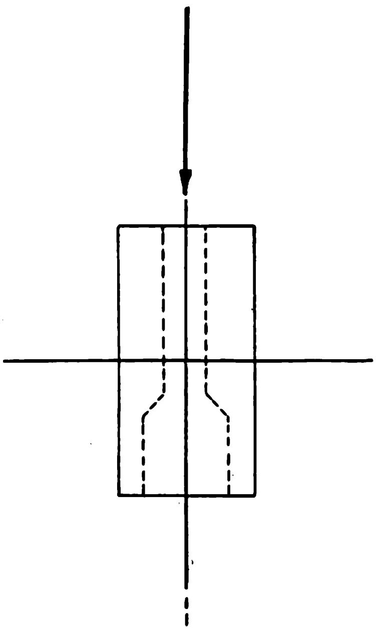


FIG. 3.

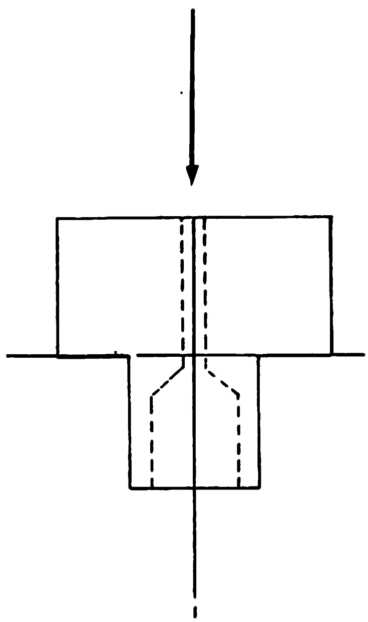


FIG. 4.

we make the diameter of the opening $\frac{1}{4}$ inch, $\frac{1}{32}$ inch, $\frac{1}{100}$ inch, or 3 inches, or whether the point of the tube has any of the shapes as shown by Figs. 1, 2, 3, and 4.

At the time of making the tests on the centrifugal pump the question came to my mind that if the formula $V = \sqrt{gh}$ is correct, it would be possible to get the condition of flow as shown by Fig. 5. Referring to the figure, you will note that we have a water-box discharging from an orifice in the bottom of the box. A Pitot tube is inserted in the stream with the point facing the direction of flow. To the other end of the tube is attached a rubber hose which passes over the top of the box. If the formula $V = \sqrt{gh}$ is correct, the water would be capable of rising to a distance above the point of the tube, by an amount equal to twice the head which

produced the velocity where measured. Thus, the water would flow back into the tank, which condition of affairs we know to be absurd.

I rigged up a large water-box and tested in this manner each of the various tubes shown by Figs. 1, 2, 3, and 4. Various velocities were allowed to act on each tube by inserting each tube in the stream at different distances below the box. In every case the water in a glass tube connected to the Pitot tube rose to the level of the water in the box. The two levels were actually measured by micrometers and the differences in all tests were within $\frac{1}{100}$ of an inch.

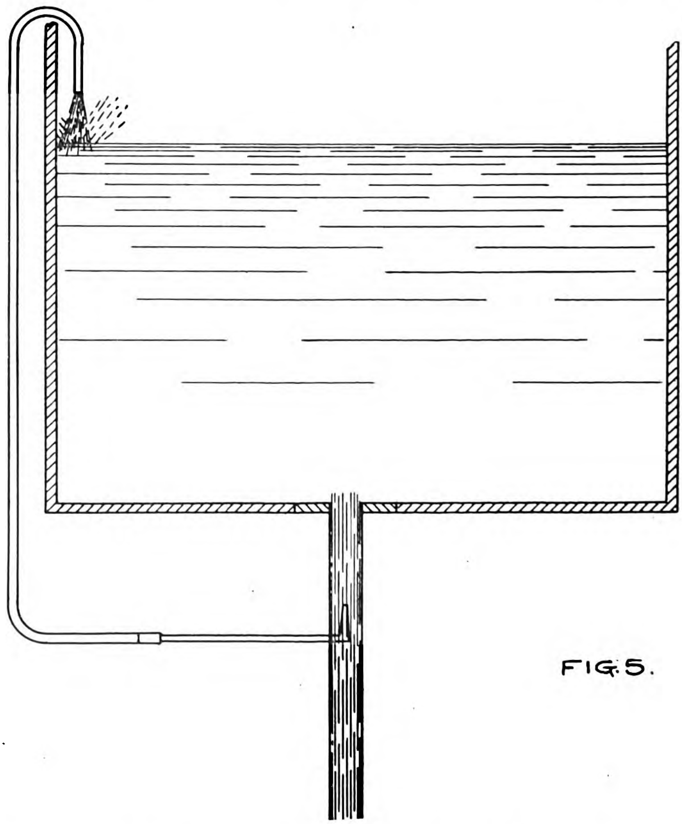


FIG. 5.

These tests were supplemented by others in which different forms of nozzles were used for discharging the water from the bottom of the box. In all cases, no matter what the diameter of the stream might be or the shape of the nozzle discharging it, the result was the same in every case.

After the completion of these tests, I went to the open channel method. Two boats were placed side by side with their center lines 6 feet apart, and a decking was built over them, forming a catamaran. A boom extended out in front of the

bows of the two boats and a Pitot tube was attached to the boom at a distance of about 2 feet in front, so that the tube would not be affected by disturbances at the bows. A glass tube was connected to the Pitot tube, and in it we could read the height to which the water would rise in the tube.

Directly above the Pitot tube and attached to the boom was a sharp knife, which extended down below the water surface. A scale was marked upon the knife and it was so related to the scale on the gage board to which the Pitot tube was connected that the reading on the knife scale at the surface of the water gave the zero of the Pitot scale. It was then an easy matter to calculate the difference between the surface of the water and the level of the water on the Pitot tube scale. Therefore, by reading the velocity head, we could calculate the velocity from the formula $V = \sqrt{2gh}$, and this velocity checked the velocity of the boat as near as could be measured.

The tests ran over a period of three or four months, for all conditions of velocity, depth, and shapes. As long as we would stick to the first principles of the Pitot tube, we found that when the point of the tube was struck with a certain velocity, the results would adhere strictly to the formula $V = \sqrt{2gh}$.

The great trouble which engineers have had in the use of the Pitot tube has resulted from the introduction of the piezometer end of the tube. I noticed to-night in Mr. Berry's paper where one of his constants between the point of the tube and a piezometer attached to the wall of the pipe was 0.997. In all cases where the Pitot tube has been used in pipes varying in diameter from 4 inches to 12 feet we have always found, as nearly as could be determined, that the coefficient of the Pitot tube is unity when referred to the pressure within the walls of the pipe.

In a recent test on the 10,000 horse-power turbines which were designed and built by the I. P. Morris Company, of Philadelphia, for Station No. 3 of the Niagara Falls Hydraulic Power and Manufacturing Company, about $3000 was spent in calibrating the Pitot tubes by two Francis weirs.

We had two weirs, each 18 feet long, with a head of 2 feet on the crests. The water was collected in a basin and discharged through two 5-foot diameter pipes. In each pipe we took two traverses with two Pitot tubes, one traverse being at right angles to the other and in the same plane, with the necessary piezometer points at the wall of the pipe. The coefficient of these tubes ranged from .97 to 1.00.

If we place the point of a Pitot tube at right angles to the direction of flow, we would then naturally assume that the reading of the tube would be the pressure head corresponding to the pressure in the pipe. Such, however, is not the case. For this particular position of the tube there is a suction action at the point of the tube, which draws the level of the water below the level corresponding to the pressure head, and the amount of this suction, of course, varies with the velocity and with the angle the tube makes with the direction of flow.

If we reverse the position of the tube so that it faces down-stream, you would expect that the suction action would be the greatest for this position. Such, however, is not the case; the suction effect here is less than that for the 90-degree position.

Let us consider a curve of this suction effect for various angles obtained by revolving the tube 360 degrees. (See Fig. 6.) Let us draw a circle and call it the

zero line. If the tube be placed so that it faces up-stream, and assume that the velocity of the water is 8 feet per second, we will get a positive reading of about one foot.

Let us lay eight feet off on this scale outside our zero line and where the angle

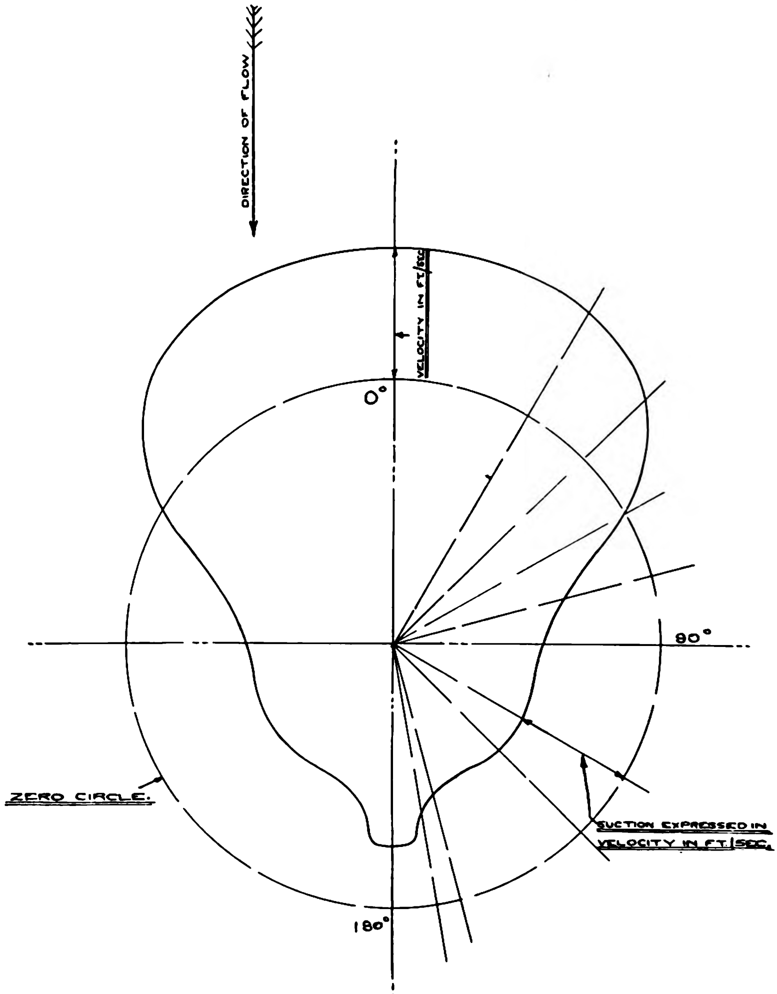


FIG. 6.

is zero degrees. Then turn the tube through 90 degrees and we get a suction effect which gives a negative reading. This negative reading expressed in velocity in feet per second is plotted in toward the center of the zero circle at the 90-degree position.

Let us do the same thing for the 180-degree position, and we find that this point will not fall very far within the zero circle. In the same manner plot the points for various angles and draw a curve through them. We find that the curve is pear-shaped.

Let us consider for a moment the reason for such varied results from the Pitot tube. Consider a Pitot tube arranged as follows. (See Fig. 7.) The piezometer end being a tube made up of $\frac{1}{4}$ inch pipe, $\frac{1}{4}$ inch tee, and $\frac{1}{4}$ inch plug with hole drilled through the side of the tee. If the point and pressure tubes are connected to a common gage, the difference in readings will be greater than the velocity

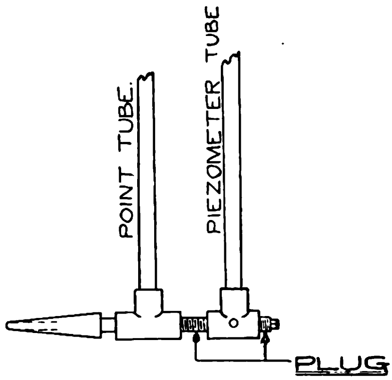


FIG. 7.

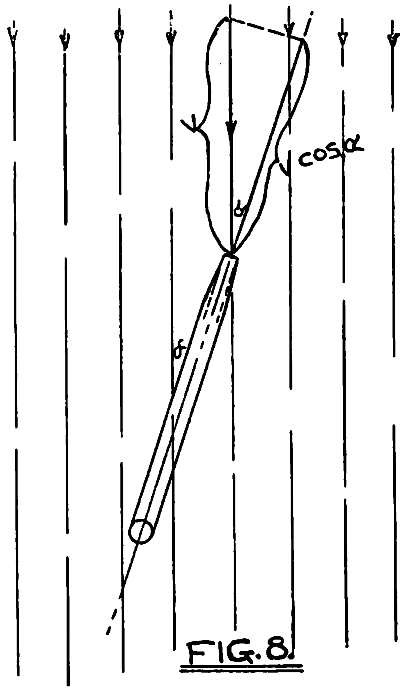


FIG. 8.

head $\frac{V^2}{2g}$ and may be expressed as $h = \left(\frac{V^2}{2g}\right) K$, where K is greater than unity. Then the formula as ordinarily used becomes $V = \sqrt{\left(\frac{1}{K}\right) 2gh}$, where $\left(\frac{1}{K}\right)$ is the constant which is less than unity. This constant, however, only applies to the pressure part of the tube, and depends on the particular shape of this part. Thus, in the tubes discussed to-night the constant varied from about .79 to .85, this constant depending on the suction action. The tube which had a constant nearest to unity was the one having the pressure opening at the back. This agrees with the curve shown by Fig. 6, which shows minimum suction at the back.

It is a pity that the elements of the tube are not clearly explained in the usual

papers. Engineers who are not familiar with them or the tube are confused and have doubts as to the reliability of the instrument. I satisfied myself ten years ago that the coefficient of the point of the tube is exactly unity under all conditions.

In using the Pitot tube there is another point to be taken into consideration, this point having come to light in my own work, within the past year. In the testing of turbine wheels we have a great amount of this work to do, and consequently a considerable amount of calibrations to make.

In turning the point of the Pitot tube at a slight angle with the direction of flow, we would expect the tube would read the resolved velocity, or V cos a. (See Fig. 8.) Such, however, is not the case. The tube does not read V cos. a, nor does it read V, but somewhere between the two. Water flowing in a pipe never flows along the smooth lines that we imagine it does. As a matter of fact, the velocity is changing at all times, and eddies and whirls are being constantly formed. We thus have little cross-currents passing before the point of the tube, and instead of the tube reading the components of these whirls in a direction parallel to the axis of the pipe, it reads values between these components and the actual velocities in the cross-current. The tube, therefore, reads slightly high, and this explains the reason why in the Niagara tests the weirs gave a slightly less quantity than the Pitot tubes.

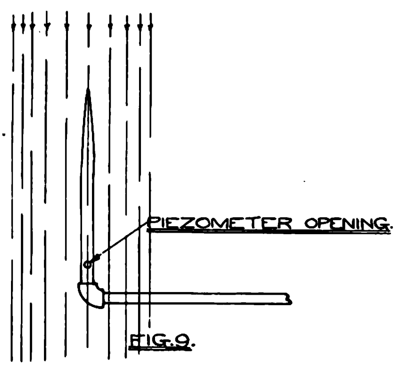


FIG. 9.

PROF. EASBY.—Could a tube be made having a coefficient of unity in which the pressure is not measured at the wall of the pipe, but by an auxiliary piezometer tube connected with the point of the tube? Also, is there any suction action at the piezometer when it is connected to the wall of the pipe?

MR. WHITE.—In order to have a tube consisting of both velocity opening and pressure opening, which would have a coefficient of unity, it becomes necessary to design a pressure opening, at which there will be no suction effect.

When this problem first presented itself to me, I went back to the water-box and endeavored to find a tube that would go into the water and would not read suction, no matter whether we moved it up or down. I finally found that in a certain long-shaped piece of pipe, drilled through the side, I had what was wanted. (See Fig. 9.)

When this tube was placed in the stream either 5 inches or 5 feet down from the box, the water within the glass would always rise to the height of the pressure openings of the tube.

I then constructed a tube similar to that shown by Fig. 10, which combined the point of the tube with the new piezometer attachment. The instrument was then tested by hauling it back and forth through the canal, and the coefficient of that tube was practically unity; I do not remember it exactly now, but it was certainly not off one per cent. The tube was tested for velocities as large as 10 feet per second.

In reply to Professor Easby's question regarding suction action at a piezometer connected to the wall of the pipe, would say that this would occur only in cases where the wall of the pipe at the point where the piezometer is attached is inclined away from the direction of flow. When the wall is inclined toward the flow the piezometer will read a portion of the velocity head and the pressure in the piezometer will be increased accordingly.

On a test recently made in California we had eight piezometers around a 5-foot diameter pipe, all of these leading up to a gage board. We had two Pitot tubes at right angles to each other, and velocities of 15 to 20 feet per second in the pipe.

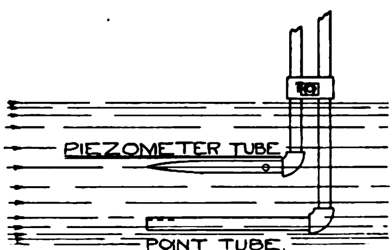


FIG. 10.

The piezometer readings would vary from ½ inch to 1 inch when the difference between them and the tubes themselves was 6 feet. Of course, as the velocity was lessened, this difference in the piezometer readings was reduced to nearly zero.

Mr. Berry.—What is the advantage, Mr. White, of having a coefficient of unity?

Mr. White.—By using a tube having unity for a coefficient, we know that we are right and can rely on the results obtained, no matter what the conditions of velocity or pressure may be. On the other hand, by using a tube having a coefficient of less than unity, an advantage might be claimed due to the larger reading obtained on the gage; but the coefficient is very uncertain, and varies not only for different tubes, but for the same tube under various conditions of flow. Owing to this fact the results are very unreliable. Therefore, if I were going to make a test I would insist on a tube with a coefficient of unity.

Prof. Easby.—Do you calibrate your Pitot tubes?

Mr. White.—No; because I have not used the tube with the coefficient. My practice is to use the Pitot tube and the piezometers at the wall of the pipe and assume the coefficient to be unity, correcting for this whirl that I mentioned due to the water not flowing in straight lines. If the whirling water has a forward

motion of 12 feet per second, the absolute velocity is greater than 12 feet per second. Owing to these conditions we must introduce a slight coefficient for the tube. The question of the calibration depends upon the conditions of flow; the coefficient of the point of the tube is unity.

Mr. Berry.—I wish to thank the gentlemen who have taken part in the discussion.

In regard to the value of the coefficient, I may say, in accord with Mr. White, that if you consider those traverses shown between the "front" and the "wall" the coefficients are all practically unity. I have shown you traverses for which the coefficients based on the data taken for the "front" and "wall" readings are almost exactly unity, and that for tubes of three different types. We feel that if it were known how to get the back or wall pressure correctly we would obtain unity for the coefficient of any form of tube with an opening directed exactly against the moving stream.

If we draw a flat plate through the water with an opening at the side connected to a gage, we will get a greater suction than if we use a tube with an opening directed exactly backward to the direction of motion. This accounts for the greater readings and consequent smaller coefficients of those tubes with the openings at the side as compared with those with the back opening pointed with the stream.

We turned one of the tubes to the right and the left of the direction of motion and made ratings with it set at different angles up to and beyond 90 degrees, when the front becomes the back. It gave when plotted a complex, lobed figure. The effects were small for a divergence of about 5 degrees and we did not follow it up further.

It would seem that the close agreement of the value of the coefficient with unity would be a matter of small consideration in the practical use of a tube. If the observations are worked up by using a coefficient which varies in the least from unity, the labor of using one number is as great as another, and, practically, a tube with a small coefficient gives larger differences on the gage for the same velocity and consequently may be used with corresponding greater accuracy. If the observations are reduced by the use of a rating curve, practically, it makes no difference if the coefficient is unity or a smaller number. The ratings for those tubes with the small coefficient and consequent greater "heads" and greater suction action due to the size and position of the back opening, were as straight lines when plotted on logarithmic paper as the ratings of the tubes with coefficients approximately unity, and in so far as such consistency of action can do so, would give values of weight equal to those from tubes with unity for a coefficient. And even though we may not now be able to account for the difference of the action by the use of theoretic hydraulics, the very consistency of the results and the greater sensitiveness of the apparatus commend the tube with the low coefficient.

A form of tube was designed essentially like a short piece of pipe with a stem soldered to it at right angles to the axis of the cylinder, having a small opening through it connected to a gage. It was thought that this tube would reproduce the conditions of a closed pipe under very small pressure, and that the readings on the column connected to this piezometer opening would bear the same relation to the front and back readings of the tube that the wall readings did when the

tube was used in a closed pipe. It did not do so, however, and the "piezometer tube" was used very little after a few runs were made in rating it.

It seems that it would be practical to make use of the Pitot tube instead of the standard current meters for the measurement of shallow streams, ditches, and canals. The apparatus is just as sensitive, quicker in its indications, is more easily transported, is less liable to damage in carrying, should retain its calibration better, and should be much cheaper if made by a first-class instrument-maker in reasonably large numbers.

PAPER NO. 1086.

NOTES ON WOOD PRESERVATION AND CREOSOTE PRODUCTION IN EUROPE.

E. A. STERLING.
(Active Member.)

Read February 19, 1910.

A MORE general knowledge of wood-preserving operations abroad would be of high value to the engineering profession at the present time, because of the rapidly growing demand for treated timber by many large wood consumers, which necessitates the erection of treating plants or the drawing up of proper specifications if the work is done at commercial plants. The first comprehensive manual in English covering the preservative treatment of wood in a broad and practical way, and embodying the results of both American and European experience, is yet to be written, so we must depend for the present on the fragmentary information available. Somewhat the same conditions which are making advisable the treatment of timber in America were back of the developments which have taken place in other countries. America is now facing a threatened timber famine and paying increased prices for poorer wood material, just as was done in Europe a hundred or more years ago before economies in the use of wood were learned and before forests were made to be continually productive, instead of being exploited like a mine. In other words, history is probably repeating itself in this case, as in many others, and no doubt many expensive mistakes could be avoided if more was known in regard to the causes underlying the failures, and the factors contributing to the success, of the work of our neighbors on the other side.

Wood preservation as a whole is a very broad subject, and brings into play some of the art and science which make up the profession of the mechanical engineer, the chemist, and the forester. Historically, it goes even farther and involves economic questions in relation to supply and demand, and is included among the functions of paternal governments through the possibilities it offers of helping conserve timber resources by increasing the life of wood material used. In

this country timber treatment is looked upon primarily as an economic measure which benefits the user by reducing timber renewals and making available many cheap woods which would be valueless without treatment. From the broader standpoint, it contributes in a large measure toward the conservation of our forest resources by reducing the consumption.

To discuss even the fundamentals of the timber-treating business would lead beyond the limits of a brief paper, and in addition would be a recapitulation of what is already familiar to most engineers;

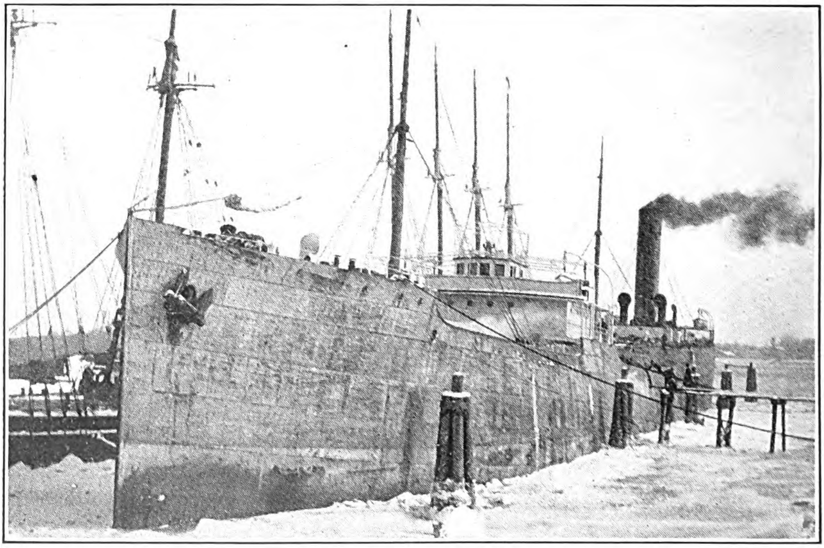


Fig. 2.—The Steamship "British Sun" Discharging Creosote Oil at Point House Pier, Philadelphia.

so the author will try to confine himself to actual observations made while in Europe last fall, and these even will be very incomplete, for the whole field could not be covered short of several years' investigation.

The preservative treatment of timber, as is generally known, is almost universally practised throughout Great Britain and all the countries of western Europe; the most intensive application of the work being in England, France, and Germany, although much treated material is used in Belgium, and the work is being taken up on a large scale in Italy and Norway and Sweden. The material treated

includes railroad sleepers, mine props, construction timbers which are exposed to the weather, fence-posts, telegraph poles, grape stakes, etc. The experimental preservation of wood was first attempted in England more than a hundred years ago, and it is said that one hundred and sixty-seven different processes, involving the use of a wide range of preservative materials, were tried prior to 1874. The most rapid and practical advancement in timber preservation followed the development of the railroads, and for the last fifty years the treatment of railroad sleepers has been a widely adopted policy. The preservatives or processes used have ranged from the attempted distribution of copper sulphate into the wood of standing trees by introducing the chemical into the sapwood, to the present almost universal use of creosote forced into manufactured material by pressure processes.

The Germans probably have more to teach us than any one else, for they have experimented with a greater number of preservatives and processes and are still working more or less along experimental lines. The French railroads, on the other hand, have perhaps achieved the most substantial results, since they have long been advocates of straight creosote and have injected into the wood all that it would hold. The English railroads have also been consistent users of creosote, and although they have experimented with other preservatives, the general practice has changed but little in recent years. Out of a total of 70 treating plants in the western countries of Continental Europe, 47 are in Germany, 14 in France, and 9 in Belgium. Of this total, 14, or 20per cent., are railroad plants, the remaining 56 being under private control, although much of their work is done for the railroads and for the government telegraph and postal services. By countries, the 9 plants in Belgium are all private, while 6 out of the 47 in Germany and 8 out of the 14 in France, or 12 per cent. and 58 per cent., respectively, are owned by the railroads.

It is known that Europeans have been achieving definite results in timber treatment for half a century, and it is therefore rather disappointing to find the mechanical equipment at their treating plants far inferior to the newer and better equipped plants in this country. Owing to the cheapness of labor, they have not learned to use mechanical devices to facilitate the handling of material in and out of the cylinder and in the yard, and practically everything is still done by hand in a way which in this country would appear slow and laborious. Their cylinders, as a rule, are small, and the doors heavy and cum-

bersome and slow to operate. The machinery is usually in keeping with the cylinders, and the pumps, etc., rarely have the capacity of those in this country. In one respect, however, their plants excel American, in that the buildings are usually of substantial brick construction and the heads of the cylinders entirely shut off from the operating room.

The railroads of Germany are naturally the largest consumers of treated material in the empire, and their policies reflect the general tendencies of the country. Practically all of the railroads are owned and operated by the states, and consequently there are a number of separate railroad organizations, all controlled to an extent by a central committee which insures through traffic arrangements and somewhat uniform policies, although each road is independent in matters relating to wood preservation. The Prussian State Railway is the largest and most influential, and in the maintenance of some 25,000 miles of track, uses from four to five million sleepers annually, about 40 per cent. of which are of metal. In the whole of Germany about eight million sleepers are consumed yearly, about 70 per cent. being wood.

It is in connection with the preservation of sleepers by the Prussian Railway that the most striking recent change in policy has taken place. Zinc chlorid, either alone or in mixture with creosote, has been extensively used, but during more recent years the full-cell process with straight creosote has been practically the standard, and many ties treated in this manner are now in track after twenty-five to thirty years' service. Despite these excellent results, however, an open-cell treatment of less certain value is being substituted for the full-cell process, the prime motive being the saving in initial cost resulting from the use of smaller quantities of creosote per sleeper. The so-called open-cell process adopted is covered by the Reuping patent, and although sound in principle and of practical application, it has not been thoroughly tried out from the standpoint of eliminating decay.

The Prussian State Railway has only two plants under its direct control, one at Northeim and the other at Zernsdorf; but there is a total of twenty-six plants in the State of Prussia which do work for the State Railway.

Much of the railroad treating work is done by the Rutgerswerke, a large corporation which owns and operates fourteen treating plants in Germany and several tar-distilling works, as at Rauxell, Berlin,

and Manheim-on-the-Rhine. This company originated the so-called Rutgers process, which is a treatment with a mixture of zinc-chlorid and creosote, and for several years treated sleepers and other timbers by this method and also with zinc chlorid alone. It was found, however, that the zinc chlorid, either in mixture with creosote or separately, leached out rapidly, failed to give adequate protection from decay, and from the railroad standpoint was unsatisfactory, because it caused the corrosion of spikes, plates, and rails in contact with it. Since their own process proved unsatisfactory, the Rutgerswerke have acquired the right to use the Reuping patent, and are rebuilding several of their plants so as to treat by this process. The Prussian State Railway, in turn, has accepted the Reuping treatment, and practically all of their work is being done by the Rutgerswerke. Although the Reuping patent has been in force only six or seven years, the Prussian Railway engineers seem to have concluded that this treatment gives as deep a penetration as is possible by any method, is permanent, does not corrode metal which comes into contact with the treated wood, and that the saving in oil—and therefore in cost—justifies the change on grounds of economy as well as efficiency. Beech ties which were treated with 36 to 40 kilos of creosote by the full-cell process are now to be given a treatment of 16 kilos, while pine ties will be impregnated with 7 kilos, although 18 and 9 kilos, respectively, were recommended by the Rutgerswerke.

The Reuping process was introduced into this country about five years ago, and the Santa Fé Railroad uses it exclusively at its large plant at Somerville, Texas. This process consists of an initial air-pressure of 40 to 80 pounds, depending on the species under treatment, followed by the introduction of the oil under an increased pressure, so that at no time is the initial pressure lost. The higher oil-pressure is held for a period varying from one to three hours, after which the oil is drawn out or forced back and a vacuum of 20 to 25 inches formed for thirty minutes to an hour. The time periods and the pressure are varied quite materially in accordance with the characteristics of the wood under treatment; well-seasoned pine, for instance, requiring only two and one-half hours; oak, about four and one-half to five hours; and beech, which in Germany is given a double Reuping treatment, seven to eight hours.

Another treatment which has been used to considerable extent in Germany, and of which little has been heard here, is the so-called creo-air process. This process eliminates the initial air-pressure, and the

amount of creosote desired per cubic foot, plus what will be drawn out by the final vacuum, is forced in. The pressure is then released, the oil blown back, and the oil which remains in the outer layers of the woods is distributed by an air-pressure running up to 175 pounds.

In addition to the two plants owned and operated by the Prussian Railway, the state railways of Bavaria control one treating plant at Kirchseeon, the roads of Saxony, one at Wülknitz and another at Falkenstein, and the Würtemberg Railway, a plant at Zuffenhausen. Creosote is coming to be the standard preservative at all of these plants, as well as at most of the private plants, although mercuric chlorid and zinc chlorid are still used to some extent.

Personal visits were made to several plants in Germany and the treatment of charges at each plant was followed. Ties which had just been treated and others which had been stored in the yard for some time were selected and cut to determine the depth of penetration by the several processes. A brief description of typical plants may be of interest.

The plant of the Bavarian State Railways, at Kirchseeon, near Munich, has a capacity of about 600,000 ties per annum, most of which are Scotch pine received by rail from the north, since Kirchseeon is in a Norway spruce region and very few treatable ties are produced locally. Occasional shipments of beech and oak are received, but they make up a very small percentage of the total. The creosoting equipment consists of three cylinders, each about 6 feet in diameter, one being 40 feet in length and holding 5 cylinder cars, and the two others about 32 feet long and holding 4 cars. Two of the cylinders are side by side and are operated by one set of machinery, while the third is in another part of the yard and is operated separately. An interesting feature of the single cylinder is that the boiler is directly underneath it, the aim being to utilize the heat from the boiler in helping keep the cylinder warm. The mechanical equipment, from the American standpoint, is quite inadequate, one feature being the absence of oil-pressure pumps of any considerable size; while all of the machinery was found to be out of date and of insufficient capacity for rapid and effective work. All of the ties are thoroughly air-seasoned before being treated, and the hewn hardwoods are run through a primitive adzing machine operated by hand, in order to surface the portion of the ties under the rail. The average treatment requires about four hours, and the process consists of an initial vacuum, followed by the introduction of the oil;

then an air-pressure of two atmospheres, which is held for about half an hour; the pressure is then dropped to zero, followed by another air-pressure of nine atmospheres, which is held for two to three hours; while at the end a slight vacuum is produced. The name of the process could not be ascertained, and it is likely a local treatment based on the experience at this particular plant. In addition to the pressure creosote treatment, a small number of ties were being treated with mercuric chlorid by a non-pressure process, the solution being placed in a long series of open tanks into which the ties were introduced and kept submerged for about six days.

The most interesting features of the Kirchseeon plant are in connection with the yard, which is large, well laid out, and provides storage capacity for nearly a million and a half ties. A distinctly up-to-date feature was the use of an electric moving platform running transversely across the yard and bisecting all of the narrow-gage yard tracks at right angles. The cylinder cars are loaded at various points in the yard, run down to and upon the moving platform by hand, and transferred bodily to a point near the treating cylinders; then on to a turntable, where they are turned and run upon a track leading to the cylinders. Here, in striking contrast to the electric platform, is a hand windlass with which the trains are pulled in and

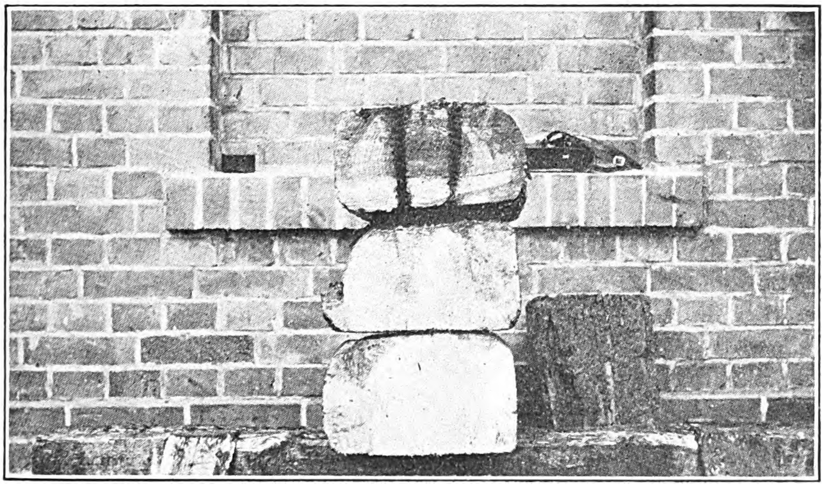


FIG. 3.—Cross-sections of Zinc-creosote-treated Pine Tie which had been in Track Twenty-three Years.

drawn out of the cylinders. Two sawmills are located in this same yard and are operated in connection with the plant. Pine timber which comes from northern points is received in the log and these little mills saw this round material into sleepers and lumber. The close utilization practised in these sawmills would be a revelation to our lumbermen, every piece of wood being converted into some usable material; even fine inner bark was being shredded and shipped away for packing purposes. As a final provision for getting the most out of everything, a large dry kiln is maintained, in which lumber which would suffer from air seasoning is taken care of.

The plant of the Rutgerswerke at Custrin, near Berlin, is equipped with three cylinders, each about 6 feet in diameter and 30 feet long. This is one of the plants which has been equipped for the use of the Reuping process, and most of the charges are given this open-cell treatment; although the creo-air process is occasionally used. The capacity of the plant by the Reuping treatment is about 3000 ties per day, the time required to put through a Reuping charge being about one and one-half hours, as against one and one-quarter with the creo-air process. Ties are treated for the Prussian State Railways and telegraph poles for the Imperial Post-office Department. The timber used is practically all pine, which is rafted down the Oder or Wartha Rivers from the Baltic region. The ties are transferred rapidly from the river to the yard by a pair of endless chains, corresponding to the jack chains in a sawmill, which operates up the river bank at an angle of about 30 degrees and drops the ties into cars at the edge of the yard. In the yard the ties are piled by the 1 x 7 system and allowed to remain until thoroughly seasoned. The dimensions are 16 x 26 c.c. x 2.7 meters for No. 1 ties, and 14 x 24 c.c. x 2.7 meters for No. 2 ties. The treatment by the Reuping process penetrates the sap entirely, but forces no oil into the heart; while the creo-air process does not even completely penetrate the sap. In the treatment of the seasoned ties, the aim is to leave in about 7 kilos of oil per tie by the Reuping, and about 6 kilos by the creo-air process. The yard at Custrin presents no features of particular interest, the cylinder cars being transferred to the cylinder on a small moving platform drawn by a horse. The movement of the trains in and out of the cylinder is by means of a steam hoist and cable. All of the ties are surfaced before treatment and cut to a uniform thickness under the rail by a machine which automatically adjusts itself to any minor variations of thickness between the two ends of a tie.

The Rutgerswerke two-cylinder plant at Stendel was one of the most interesting visited. The mechanical equipment is better than at most of the European plants, and the results obtained in the treatment of beech—which is the only species used—are very excellent. The air-seasoned beech ties are treated by the so-called "double Reuping" process, the absorption being about 16 kilos per tie and requiring about seven hours for each charge. The penetration by this process is practically complete for about two feet on each end of the tie, while a cross-section from the middle of the tie usually shows only two or three small spots which have not been touched by the oil.

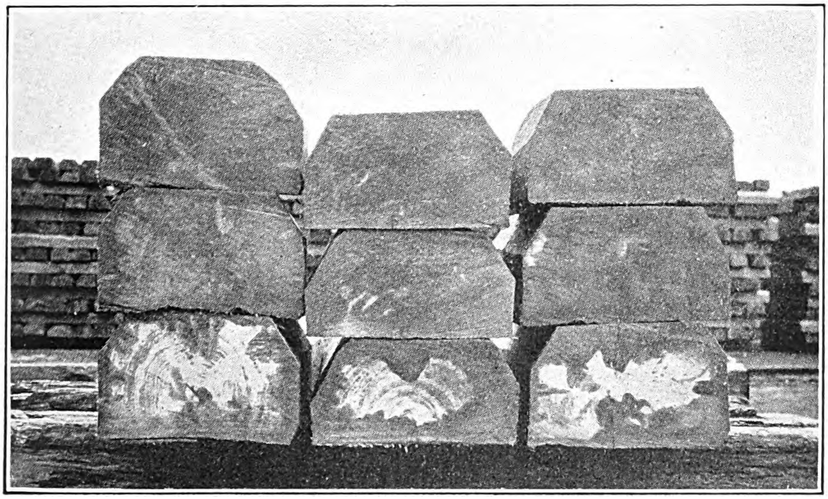


Fig. 4.—Beech Ties Treated by the Double Reuping Process, 16 kilos per tie. The two top sections were cut two feet from the ends of the ties, the bottom sections from the center.

It was noticeable that the penetration was somewhat more complete in ties which had been treated and stored in the yard for some weeks than in those which had just come out of the cylinders; this being due to the gradual absorption of the oil by the untreated portions upon cooling. The accompanying photographs of beech ties show the character of the penetration with the double Reuping treatment.

It is quite generally admitted, even by the advocates of the Reuping process, that conclusive data regarding the relative value of the full- and open-cell treatments are not available, because the latter has not had the test of time. In order to hasten decay and obtain

quicker comparative results, a very interesting "fungus pit" is maintained at Stendel, in which conditions favorable to the decay of test pieces of treated and untreated wood are created, and definite series of experiments are carried on to determine the relative efficiency of different processes. The decay chambers are underground in what amounts to a cellar with concrete walls and floor, underneath a small brick building which is used for a museum and laboratory. This cellar is partitioned off into four small rooms, one containing the heating apparatus, another being used for the propagation of various species of fungi, and the other two as test rooms. The temperature in the decay pits is maintained at from 17° to 21° C., and moisture is provided for by pockets in the concrete wall and also by keeping a stream of water flowing between the concrete wall and a false wall of brick. The wood-destroying fungi are propagated in zinc-lined boxes on small blocks of wood, which are used as needed for infection purposes by placing them in contact with the test pieces in one of the other rooms, the fungi on the infected pieces developing through the dissemination of spores or by the direct growth of the hyphal threads. The conditions produced in this way are so favorable to the decay of wood that untreated pine rots entirely away in seven or eight months, thus giving comparative results as between treated and untreated woods, and between different methods of treatment, in a very short time.

In France there have been no recent changes in the methods of treating railroad timbers, the full-cell process with creosote being exclusively used, although for some years zinc chlorid and other mineral salts were in favor. Open-cell processes and metal ties are condemned by most of the railroads, and the conclusions are probably sound, because based in most cases upon actual experiments. The French State Railway some years ago made extensive experiments in reducing the amount of creosote used per tie, but it was found that the ties decayed more rapidly, and the cheaper treatment was abandoned. Similar experiments have been made by the Paris-Lyons-Mediterranean Railroad with the same results, and the sentiment seems to be that the injection of large doses of oil will be the most economical in the long run, although the initial expense, of course, is materially higher. The latter road owns and operates two plants and uses the product from three private plants. The State Railroad of France owns three plants, the Northern Railway of France, three, and the Eastern Railway, one.

The experience of the Paris-Lyons-Mediterranean road is, perhaps, typical, this road using about one million creosoted sleepers per year, mostly of beech, although small quantities of oak and pine are used. Creosote is the only preservative considered, and no untreated ties are put in track. In size their No. 1 sawed ties are 2.6 meters long x 15 c.c. x 21 c.c. square. The untreated ties, delivered at the treating plants, cost about 85 cents for beech and from 60 to 75 cents for oak and pine. With a 20- to 30-pound treatment with creosote per cubic foot, beech ties give a life in track of from twenty-five to thirty years, the treatment costing from 45 to 80 cents.

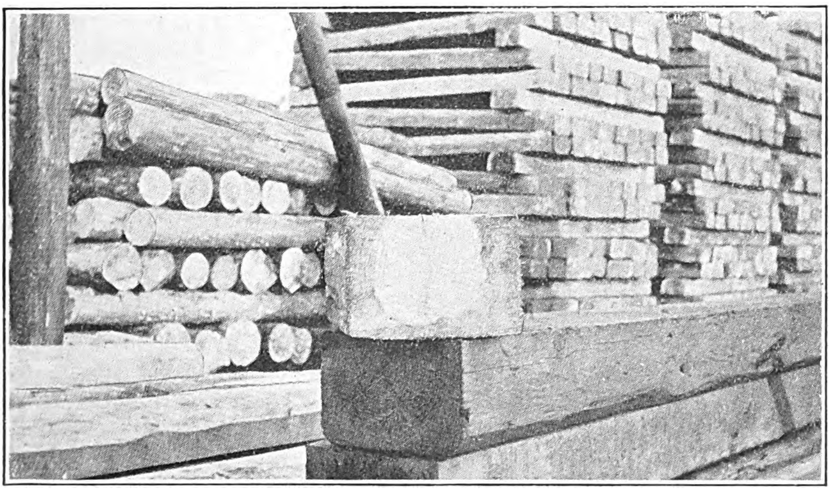


FIG. 5.—Scotch Pine Tie Treated by the Reuping Process. The Sapwood only is Impregnated.

The practice of the English roads in creosoting sleepers offers little that is new or instructive. With the exception of the London and Southwestern Railway, which still uses the open-tank treatment, most of the roads treat under pressure and specify a full-cell treatment. The material used is mainly Baltic pine obtained from Continental Europe. Very little experimental work is done, and with the exception of 50,000 ties treated for the Great Northern Railroad by the Reuping process, little or no attempt has been made to economize in the use of oil by an empty-cell process. Most of the roads control one or more plants, but at the same time depend to a large extent upon private concerns for the creosoting of their material.

5

The general practice of renewing certain sections of track periodically instead of "spotting in" the ties, as is the custom on American railroads, results in the fullest use of the creosoted sleepers. It is not uncommon for ties to remain in track for ten years, when they are taken up and the majority used again in main-line track for another ten years, at the end of which time those which are in fairly good condition are taken up and put in side tracks. The result is that from twenty to thirty years' use is obtained from a considerable percentage of the creosoted sleepers.

Among the lessons which can be learned from the experience of

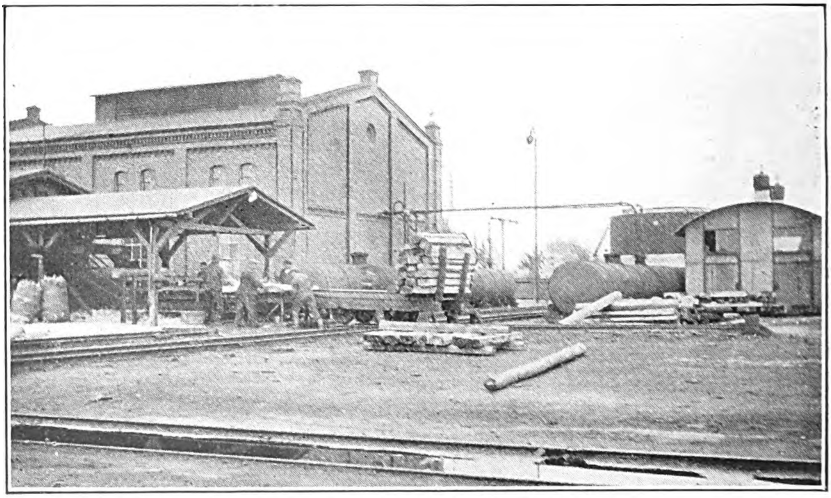


Fig. 6.—Tie-adzing Machine at Stendel, Germany.

European railroads in the preservative treatment of sleepers and other wood material is, that it pays to treat all the ties which go into track, and that it is economy to accept as far as possible the cheaper, inferior woods which have little lumber value, but which, with treatment, will be entirely satisfactory for cross-tie purposes. Oak, for example, is not generally used for cross-ties abroad, its place being taken by beech, which is not suitable for general construction purposes. This has the effect of greatly reducing the demands on the limited supplies of the more valuable and more generally used oak. Another development which has been carried much farther on the other side than here is the elimination of mechanical abrasion as far

as possible by the use of screw spikes and tie-plates, and although the wheel loads and the amount of traffic are less than on our main lines, it would be looked upon as almost criminal negligence not to provide the maximum protection from mechanical wear even under the less exacting conditions which prevail. An important factor in this connection is the surfacing of all ties under the rail base before they are treated, thus permitting the tie-plate to rest firmly upon the tie and eliminating the extra wear which naturally follows if the tie-plate is not firm. The better mechanical equipment and the various labor-saving devices which are characteristic of American

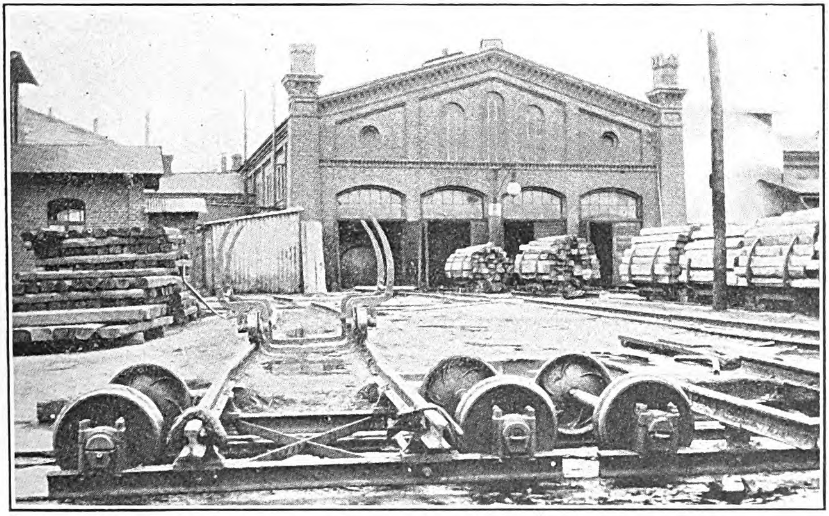


Fig. 7.—General View of the Cylinder Building at Stendel, Showing Moving Platform and Empty Tie Car in the Foreground.

wood-preserving plants are the actual result of a difference in conditions, and it would be unfair to criticize our European friends, who have taught us so much, because their plants are mechanically inferior to ours. They no doubt realize that the equipment of many of their plants is inadequate and out of date, but they hesitate, as one would under similar circumstances, to make the necessary expenditures for new equipment as long as the old can be made to give fairly satisfactory service. With labor costing 50 to 75 cents a day, as against $1.50 to $2.00 here, there is not the same necessity for labor-saving devices as here. The treatment of green timber is

rarely attempted at any of the European plants, and practically all of the material is air-seasoned for a period of at least twelve months. It would no doubt be well to adopt the same policy in this country, and thus eliminate the unsatisfactory steaming of green timber prior to treatment.

Aside from the facts which can be learned abroad in regard to preservatives, processes, and the results which may be expected in relation to the resistance of wood material to decay if properly treated, there is a broader lesson which should appeal strongly to every one, now that the end of the timber resources in this country has nearly

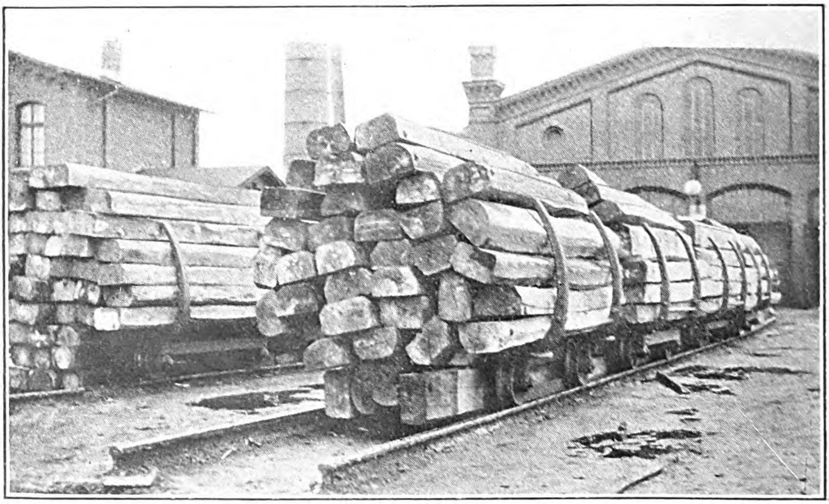


FIG. 8.—Charge of Ties Ready to Enter the Cylinder at Stendel.

been reached, and the extravagance of the past cannot be tolerated in the future. Europe has learned to practise close utilization and economy in many lines of industry, and perhaps in none more than in the use of wood. Not only are railroad cross-ties and other timbers used in large quantities by industrial concerns treated so as to give the maximum life, but the smaller items, such as posts, grape-vine stakes, etc., are preserved, and the peasant farmer as well as the State Railway contributes toward a reduction in the consumption of wood. The result of these and other economies is that Europe uses only about 60 board feet of timber per capita per year, whereas the average in the United States is about 450 board feet per year per

person, or more than seven times as great. Railroads in this country alone use over 100,000,000 cross-ties per annum, and for their timber requirements take about 20 per cent. of all of the timber cut each year, which strips the forests from no less than a million acres. If preservative treatment did no more than double the life of timber, it would cut this consumption in half and reduce the annual drain by half a million acres per year. Such action, if coupled with measures which would keep our forest lands continually productive, would soon solve all the problems of forest conservation.

In conclusion, the author desires to outline very briefly the general situation as regards the creosote which Europe produces and furnishes for consumption all over the world. The two main sources of supply are Germany and England, practically all of the other European countries deriving most of their supply from these producing countries, but mainly from Germany.

Creosote is a by-product of a by-product, it being one of the many distillates of tar, and the tar in turn being a by-product of coke ovens or illuminating gas plants, the larger percentage of that distilled being coke-oven tar. The tar from both of these sources is assembled at distillation plants, where it is refined into four main products: light oils, solid anthracene and napthalene, creosote, and pitch. The pitch, which is used for making briquettes, usually constitutes about 50 per cent. of the total, creosote, 15 per cent., and the volatile oils and solids the remainder. The light oils, such as ammonia, benzol, etc., are usually placed on the market direct, while the solids are disposed of to other chemical plants, where they are worked up into coal-tar flavoring extracts and anilin dyes.

The German distillation plants which produce most of the creosote for the American export trade are in the coal and iron districts of Westphalia. The oil produced at the various works is shipped by barge to Amsterdam, Holland, or to Emden, Germany, where it is assembled in large shore tanks and thence pumped into tank steamers for export. The creosote produced in the plants of eastern Germany, Posen, and Silesia is disposed of locally or shipped to France and Italy. A German syndicate of tar producers and distillers practically controls the whole creosote industry on the Continent, and while the individual concerns making up the syndicate sell part of their output locally as they find a market, the greater part of the creosote produced is disposed of by a selling syndicate which represents the combination of producers and distillers. This selling syndicate entirely controls the

export business, and the American consumer cannot hope to go into the German creosote market and bid for oil on a competitive basis. Fortunately, the standard set is high and the oil assembled for American trade is of uniformly good quality and is available at reasonable cost. It is obvious, however, that the German supply cannot long meet the rapidly increasing American demand, and it is not at all unlikely that there will be a scarcity of creosote oil in the near future.

England is the only other European country producing creosote oil for export, and the situation as regards supply is somewhat similar to that in Germany. The London creosote is distilled almost entirely from tar produced at illuminating gas plants, whereas the "country oils" are derived largely from coke-oven tar, and, as a rule, are lighter and of poorer quality than the London oil. The tar distillation in England is not, as a rule, carried as far as in Germany, with the result that the percentage of solid napthalene and anthracene is higher. The relative value of German and English oil for wood-preserving purposes is an unsettled question, and the American consumers have rather decided opinions on the matter, so that the present demands for oil are somewhat equally divided between the two countries. Aside from the difference in general characteristics, there are undoubtedly more variations in the English oil than in the German, and the general market is in a more unstable condition. The British producers and exporters at the present time are working independently, with the result that there is keen competition and the prices fluctuate through rather wide limits in accordance with the amount of oil available at any particular time.

The importations of creosote oil into the United States, which in 1905 amounted to about 8,000,000 gallons, had by 1909 grown to nearly 40,000,000 gallons, or an increase of 400 per cent. Out of the total creosote consumption in this country of about 56,000,000 gallons in 1908, 69 per cent. was imported, while in 1903 the total amount used was only 7,700,000 gallons. This is an average increase of nearly 10,000,000 gallons per year, and it is certain that if this continues at anything like the present rate, there will be a serious shortage of creosote in a few years. The supply in both England and Germany is unquestionably limited, and although the output of the latter country can be increased by perhaps 50 per cent., part of this will have to go to local consumers and to other European countries. The ultimate solution of the creosote supply question should be

home production. There is enough tar wasted in our beehive coke ovens to furnish creosote for all consumers, and even now, if the tar output of American by-product plants was refined, it would go a long way toward meeting present creosote requirements. The two principal factors responsible for the inadequate American creosote output to-day are the high initial cost of by-product plants and tar distillation works, and the lack of a market for some of the coal-tar products. The value of the creosote alone will not justify the distillation of tar, but American industry will not be maintaining its reputation if ways and means are not found by which the tar now produced or going to waste in this country can be made to yield the creosote and other coal-tar products which are needed.

DISCUSSION.

John Foley.—No doubt it was modesty which led Mr. Sterling to put the forester last in his list of those upon whose professional efforts wood preservation depends for successful application, because up to the present foresters have been the most active in the propaganda and experiments necessary to a more thorough and general knowledge of the great possibilities in lengthening the life of wood. As one of them, I think we can now turn the further development of processes wholly over to the chemical and mechanical engineers, while we go back to our woods to grow the timber for them to treat.

While it must be evident to every one that anything which will make wood last longer will reduce the enormous drain on our forests, it is not so generally appreciated that wood preservation is a prime factor in the conservation of our forest resources through the worth it gives to otherwise useless trees, and thus spreads over a greater variety of woods the demands made on the species employed heretofore. This creation of a market for a great many woods which, if not treated, would decay rapidly, has been the main object of the forester's efforts in wood preservation, for one of his problems is to reduce the number of weed trees he must contend with in the forest he is handling properly. The requisition now made by the Pennsylvania Railroad for beech, birch, maple, and gum timbers to be treated marks an epoch in forest management in this State; and elsewhere, too, for the Pennsylvania Railroad is getting supplies of woods for treatment from the stands of gum and loblolly pine in the south.

The very great wastes which have marked the manufacture of lumber are nothing compared to the waste due to the use of wood which has not been treated. The logger and the millman have, to a praiseworthy extent, eliminated the former, and the wood preserver will stop the latter drain on our natural resources. The conservation of these lies, not in tying them up to look at, but in employing them to the limit of their usefulness. The possibilities along that line are great; in no case more so than with forest management, which becomes more and more feasible as the value of timber increases.

Mr. Tiffany.—Dealing entirely, as this paper does, with operations abroad, makes any discussion difficult, since the work in this country is quite different

from that abroad. Consequently, I will not attempt to more than emphasize one or two statements concerning the general subject of wood preservation.

In regard to the corrosive action of creosote: the creosote we are using—which, by the way, is a German oil—will not only not corrode, but will prevent rust. A piece of iron or steel, filed to brightness, then dipped in creosote, if exposed to the weather, will not show any rust so long as the oil remains on the iron. If the creosote is rubbed off after standing for some time, it will be found that the metal is still bright.

Another part of the paper read called attention to the necessity of mechanical protection for the treated timber. There is no doubt that a preservative treatment with creosote will make wood decay-proof for twenty or twenty-five years; but there is no object to be gained by rendering a stick proof from decay for over twenty years, and then either crushing or spiking it to pieces in five or six. This is a feature to be noted in preservative treatment of wood, especially of railroad cross-ties.

To take up a discussion of methods of treatment would require a great amount of detail. The speaker, however, referred to a process by which the oil is forced into the wood by an air-pressure applied after the oil has been injected into the wood. From our experience, we have found that an air-pressure following an oil-pressure is of little value, especially when the air pressure is but 100 pounds following an oil pressure of 180 pounds. The oil has been found to distribute itself, leaving the air-pressure almost valueless.

The double Reuping process was also mentioned. In this connection, we have found that this double pressure will give a more satisfactory penetration than a simple pressure. For example, last week, in treating a charge of very refractory timber, by dropping the pressure from 200 pounds to 50 pounds and then bringing it up again, we found that oil could be forced into the wood about twice as fast as by maintaining a constant pressure of 200 pounds.

I believe that the Club will get a more satisfactory idea of the situation by asking questions than from any discussion, so I will not speak further.

P. A. Maignen.—I have made some laboratory experiments in wood preservation. They were suggested to me by certain passages in the "Primer of Wood Preservation," Forest Service, Circular 139:

> "The decay of a plant body," says the Primer, "such as wood, is not an inorganic process like the rusting of iron or the crumbling of stone, but is due to the activities of low forms of plant life called bacteria and fungi. . . .
>
> "The chief material of the cell walls is a substance called cellulose, and around these there are incrusted many different organic substances known collectively as lignin. Most of the wood-destroying fungi attack only the lignin; others attack the cellulose alone, while the third class destroy all parts of the wood structure. . .
>
> "But food (lignin) is not the only thing that a fungus requires for its growth and development, it must also have heat, air, and moisture. If any one of these is lacking, the fungus cannot develop. . . . Of the four requirements, two (heat and air) are beyond control. It is only by depriving the fungi of food or moisture that the destruction they cause can be prevented."

The removal of the moisture is easily done by seasoning, and this has been so well studied that little need be said about it. But the removal of the organic matter does not seem to have received much consideration. This food for the fungi —the lignin or organic matter—is also known as sap. In green wood it is associated with water. One may remove a part of the water from the wood as one

removes the water from apples that one wishes to preserve, but one does not remove the organic matter—the gums and resins; they remain in the wood as sugar and mucilaginous matter remain in the dried apples. When the apples are soaked in water afterward, the conditions for fermentation exist, and decomposition begins. Likewise the wood may be dried or seasoned; it keeps well as long as it is dry, but when it reabsorbs moisture it is subject to the same tendencies to parasitical decomposition as green wood.

The Primer further says, under the heading "How Decay Can be Retarded":

"The simplest way of prolonging the life of timber exposed to wood-destroying fungi is to reduce the moisture content of the wood."

And under the heading "How Decay Can be Retarded by Chemical Impregnation":

"By far the best method of checking the growth of fungi is to deprive them of food. This can be done by injecting poisonous substances into the timber, and so change the organic matter from foods suitable for fungi into powerful fungicides."

This is evidently the principle on which the present systems of wood preservation are based.

The fact which struck me as being worthy of consideration is not the removal of moisture, nor the introduction of a germicide. This has been done by others. It is the removal of the organic matter. The logging or water soaking of wood intended for naval construction is probably the best example of the idea of removing the organic matter. To find an economical method of doing in a short time what takes years in marine timber has been the object of my experimentation. What is called volatile matter in coal analyses is nothing but the organic matter spoken of above.

A process that could remove from wood the organic matter would make it more resisting against decay and reduce its inflammability as well. Creosote and other oils, on the contrary, increase its combustibility.

My experimentation is not ended. When it is completed I will gladly place it before the Club.

Mr. Foley.—Mr. Maignen made some remarks about creosoted wood increasing the risk from fire. Some qualifications are necessary in such a statement. It is true that wood saturated with creosote will burn with great intensity once it gets started, but it has been proved in many instances that the apparent case-hardening which results from the seasoning and treatment of the wood saves it from igniting as readily as does untreated wood.

R. G. Develin.—The phase of this question which appeals to the structural engineer is the desirability of using creosoted material for all structural timbers exposed to the weather. Except for piling in salt water, our eastern railroads have used very little creosoted material in the past, but I believe the time is not far distant when the greater portion of their timber consumption will be creosoted. A year ago I saw some creosoted stringers in a trestle bridge on the West Jersey and Seashore Railroad which had been in service thirteen years; one end of the stringers ran into the bank, and it was in perfect condition at the time of my inspection. It certainly seems to be a waste of money to have to renew timber trestle work every seven to nine years, as is necessary when untreated material is used.

PAPER NO. 1087.

THE FRUHLING SUCTION DREDGE.

JOHN REID.
(Visitor.)

Read May 7, 1910.

THE man who first set out to develop the use of the primitive form of the centrifugal suction pump soon found out that it was adapted for handling many things besides water. The absence of valves with their attendant troubles and frequent disarrangements would easily determine in favor of the use of the centrifugal pump for conditions in which the liquid to be pumped might be expected to contain a large percentage of solid matter. Sand, mud, and other materials much less homogeneous and capable of being pumped would often appear in the pump discharge, and from such handling of solids by accident to the handling of them by design, as in a suction dredge, is a simple and natural process of evolution.

The exact moment, however, in which it was first discovered that a new excavating agent of tremendous power had been developed cannot now be fixed with any certainty, nor can any one man apparently claim the merit for the discovery. From the most authentic information at the author's disposal, it would seem that the first serious practical use of the centrifugal suction dredge occurred in the later stages of the construction of the Suez Canal, that is, in the late sixties of last century. In passing, it is worthy of notice that the Suez Canal, which was begun under a terrible labor régime of practical slavery, ended by developing the most remarkable excavating appliances of that day, and among them the centrifugal pump suction dredge, which is at this date certainly the most powerful excavating appliance in the hands of the engineer.

But the progress of the development of the suction dredge was so slow that as late as 1879 a recognized authority on dredging writes as follows:

"Another of the recently suggested improvements is that by Mr. C. Randolph, who in 1870 proposed that instead of the ordinary dredging buckets, pipes should be lowered until they came into con-

tact with the sand and mud at the bottom. The tops of these pipes were to be in communication with powerful centrifugal pumps, so that the velocity of the inflowing water, through the pipes, could be made so great as to carry with it a large percentage of the sand or mud from the bottom, and when the solid matter and the water in which it is suspended were raised to the desired height they would flow freely to any required place for deposit of the suspended material. It is not known that this plan has been carried into practical operation."

From the date of this somewhat desultory and ill-informed reference to the present day, when the record for the suction dredge, so crudely described above, stands at 10,000 tons of sand lifted in fifty minutes by the great Mersey dredge, the "Leviathan," is a big advance, toward which many great minds have contributed. Engineers are familiar with the work of Bowers and Bates and Eads. A year or so ago, at Norfolk, Eads' original Mississippi dredge was still in active employment and doing fair work. In Europe, Simons, Lyster, Gwynn and many others have earned world-wide celebrity by the excellence of the results obtained with dredges designed by them. To these names must now be added that of Otto Fruhling, of Germany, who has in recent years brought about an improvement in the suction hopper dredge well nigh revolutionary in its results. Being a German, a practical contractor and engineer, and part builder of the Kaiser Wilhelm or Kiel Canal, it is not unnatural that Herr Fruhling should have been much disturbed by the lack of efficiency which the suction hopper dredge displayed in his work. When one is paid by the cubic yard of solids, lifted and secured, and one's dredging appliances persist in delivering a copious supply of liquids, one does not need to be born in Germany in order to feel provoked about it. But it must be admitted that engineers the world over have been marvelously complaisant over a mechanical efficiency in the suction hopper dredge so low as to be almost without parallel in engineering. Let me say here, by the way, that I am now, and in the discussion which follows, referring only to what is known as the suction *hopper* dredge, *i. e.*, the dredge in which the material as pumped is discharged into a hold or hopper in the dredge itself, in which it is transported for some distance to a suitable place for dumping. It is important to emphasize this point because a great deal of useless controversy is often created in these matters by attempting to compare the results of the hopper dredge with those of quite

different suction dredges, such as pipe-line discharging dredges or cutter-head suction dredges—all very useful tools, no doubt, in their own work and place.

The low efficiency of the ordinary suction dredge arises from two main reasons: (1) Failure to get the dredged material into the suction, and (2) failure to get it out of the discharge. The upper diagram in Fig. 1 illustrates roughly the principal features of what may be called the open-mouth suction hopper dredge, and the "Leviathan" itself, to which I have referred, is simply one of the largest and most up-to-date of this type. In this form of suction dredge there is the floating ship-shaped hull, the steam-driven centrifugal pump or

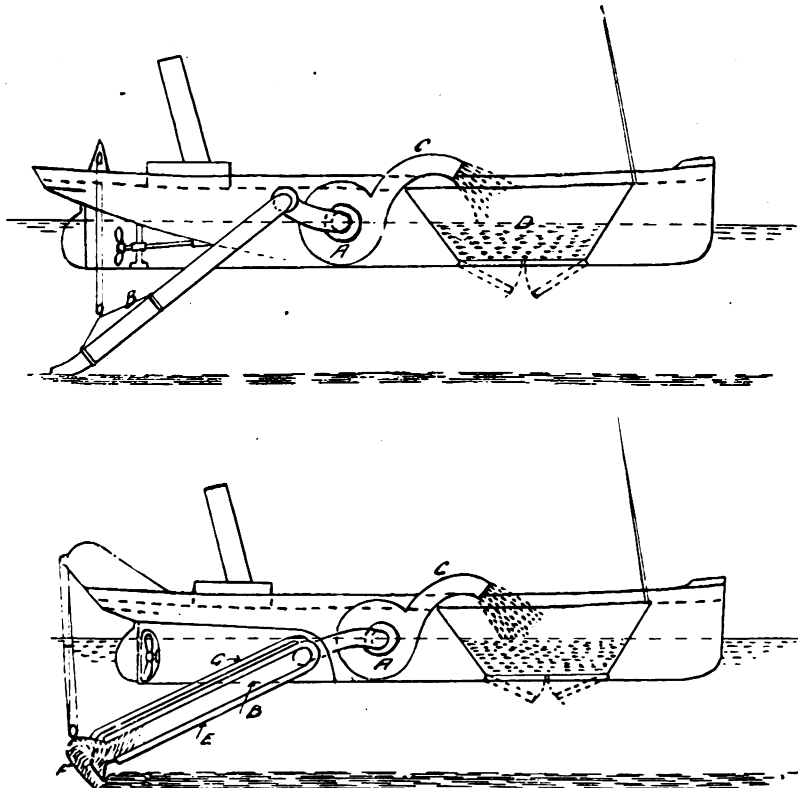


FIG. 1.—Diagrams Showing Comparison of the Fruhling with the Common Type of Suction Dredge.

pumps, and the suction legs, usually one on either side of the vessel. These legs are made of light steel pipe with rubber sleeves to give flexibility and prevent them from being torn off or injured in a seaway. At the bottom end of the suction pipes various forms of contracted nozzles are used to collect the material to be dredged and assist the suction. The mode of operation is simple; as the vessel steams slowly ahead the nozzles scrape over the surface of the material to be dredged and the suction action draws in an enormous volume of water which entrains with it various small percentages of sand, mud, gravel, etc.

It is fair to say that in capable hands, dredges of this type have done splendid work. An example is the opening of the Ambrose Channel in New York, an exceedingly difficult proposition, where four of them were employed. Plenty of them are doing good work still, and right in this neighborhood. The cutting of the Ambrose Channel into New York harbor affords also a very good example of the employment of the wrong type of dredge, which resulted in the contractors who first undertook the work sustaining a heavy loss. Two large dredges of the central well suction type were built at a cost of about $1,000,000. They were of the English Mersey type and of great power and particularly well built and equipped. But a mistake was made in imagining that the sand, mud, and clay and other mixed materials found on theAmbrose Channel would behave exactly like the clear sand of the Mersey Bar. In the latter location it is customary for dredges to anchor and fill their hoppers from one spot, by digging a deep hole, into which the surrounding sand is swept later on by the tidal current, so that finally a fairly even channel is obtained. But if the bottom does not even up in this way, one can understand that the contractor is in a deep hole himself, because on the Ambrose Channel he is paid for a channel 40 feet deep, and no allowance can be made for holes 60 feet deep and overcuts. This is what happened at New York, and the bankruptcy of the contracting firm followed. One of the dredges has been converted into what Kipling calls a "crawling cargo tank," and the other is rotting itself to pieces in idleness—a costly failure, from which the lesson can be drawn that dredges, like other tools, cannot be designed from preconceived ideas of what is probable or likely when they get to work, but must be the outcome of the closest investigations of the dredging locality and of experience under similar conditions. When one analyzes the working results of the ordinary dredge, it becomes

evident, as one would expect, that the working efficiency is exceedingly low. It is a fair statement that in ordinary sand dredging this type of dredge rarely obtains an average of 15 per cent. of useful work out of the total work done. To put it otherwise, from 10 to 15 cubic yards of sand is the usual quantity secured from every 100 cubic yards of water and sand passed through the pumps. What would be thought of a steam-shovel which could lift only 15 per cent. of its bucket capacity each trip, and which lost a good deal of each shovelful in loading the dump car? That type of shovel would have a short existence; but so cheap has the work of the suction hopper dredge, with all its defects, proved in practice that the mechanical defects and inefficiency have been treated as more or less inherent, and largely ignored. The reason for the low efficiency of the ordinary form of dredge is not hard to find. By no possible exercise of ingenuity can the intelligence of the dredge master or his crew be put in control of the suction entrance in this type of dredge. If the material is hard packed, no amount of pumping will bring up the solids; if the material is soft, one may pump a big hole where the suction happens to be, and possibly have the estimate reduced by the inspecting engineer for cutting over depth; if the dredge is in a tidal current or sea-way, the flexible pipes take charge of the situation entirely, and it has to be managed to suit them, or they are destroyed. At the hopper end there is, again, serious loss of efficiency because so much water has to be pumped which has to go back overboard, and if the materials dredged are light, they go with it, and the losses are enormous. Under the circumstances it is surprising that this dredge does as good work in sand as the records show.

When, however, one considers its work in mud and fine silt the efficiency, which is low enough in sand, becomes very much lower. This is not because the mud cannot be drawn into the suction water, but because it cannot be taken out again in the hopper. By no known means can mud be precipitated from a thin solution in any period of time for which a dredge master would be willing to stand. Take a familiar example: how long must one wait after stirring up the mud in a pool till the water is clear again, which shows that the mud has been deposited? Much longer certainly than any dredge captain could afford to wait and hold his job, and one must remember that in the ordinary dredge the hopper is in a perpetual turmoil from the enormous volume of water which the pump discharges into it,—a condition which simply precludes any precipitation of the mud

pumped, before it again flows overboard. Engineers have hitherto appeared to be so helpless in combating with this serious source of

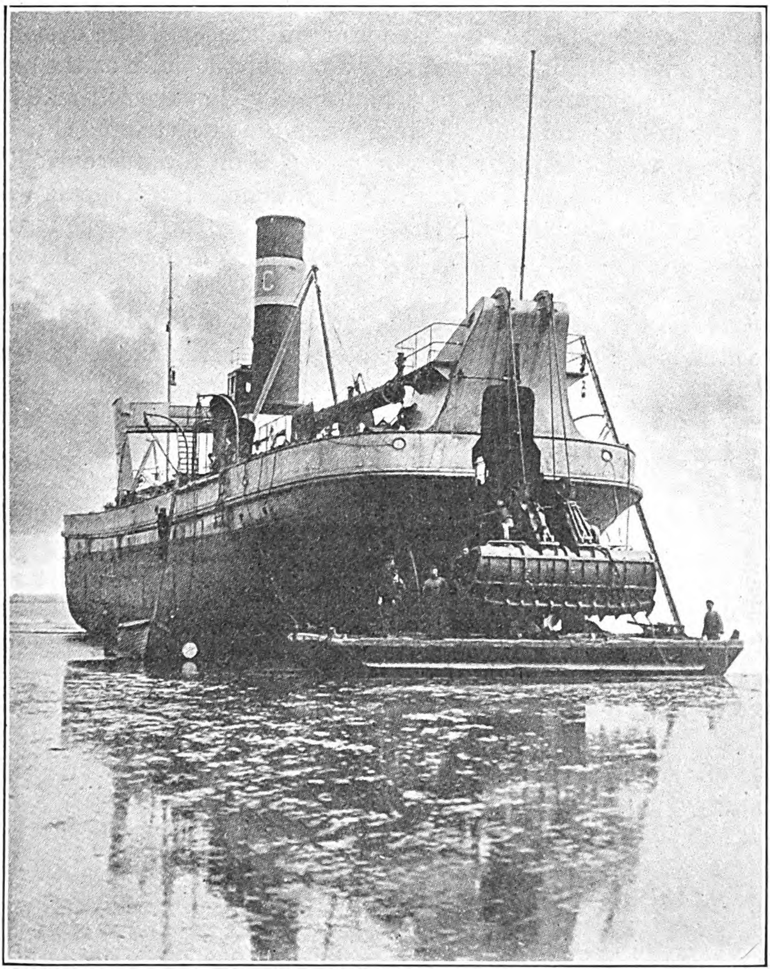


Fig. 3.—Fruhling Hopper Dredge for Canadian Government Showing Suction Head.

loss that the use of the suction hopper dredge in mud has been practically abandoned, and instead bucket ladder, dipper, or clamshell dredges and scows have been employed.

This was the state of affairs when Herr Fruhling began to investigate, with all the thoroughness of which a German is capable, the possibilities of the suction dredge in handling mud. He had a plant including a bucket ladder dredge with its attendant scows, which was slow and cumbrous and expensive in operation. The idea occurred to him, if he could fit a big bucket or dipper upside down on the head of the trailing open suction pipe, and thereby claw the soft material up, compress it, and pump it from inside the bucket while choking off the surrounding water, he would be well on toward controlling the problem which had so long baffled solution. Experiments were made on a practical scale which gave remarkably encouraging results and led to the construction of the first Fruhling dredge for the German government.

Such in brief is the history of the evolution of the Fruhling system. No flash-in-the-pan invention, but the result of careful investigations, laborious experiment, and continued improvement, extending over a dozen years. From the lower diagram in Fig. 1 one can easily grasp the general arrangement. The hull is split up aft by a dredging well in which a heavy bridge girder carries the twin suction pipes hinging about the hollow trunnion bearings at the forward end of the well. The dredge head is a steel casting with a broad cutting-edge, the angle of which can be varied for various dredging depths and dredging materials. The cutting-edge is faced with teeth containing water nozzles fed with water under pressure from a special pump of large capacity. In small dredges, the dredge head is from 10 to 12 feet wide, in large sizes from 16 to 20 feet, and weighing with the girder from 30,000 to 40,000 pounds. The dredge steams ahead on its propellers, the head is buried in the mud to a suitable depth, being supported and controlled by the wires from a hoisting winch, and it rakes or plows off a section of the bottom mud as wide as itself, which enters the head chamber, is mixed and compressed there, pumped through the centrifugal pumps, and finally discharged into the hopper, not as a swirling stream of dirty water, but as an almost semi-solid viscous body, having a consistency of from 80 to 90 per cent. solid, like molasses or builders' mortar. Care must always be taken to differentiate between the various dredging materials. In sand the operation and results are different. Sand must have a good supply of water to travel in pipes with it, especially if there are numerous and sharp bends in the pipes, as there invariably are in suction dredges. It is perfectly possible, however, in the Fruhling dredge

to compel suitable sand (of which, by the way, there are infinite varieties) to flow in a 60 per cent. solid stream into the hopper. But in ordinary working from 30 to 40 per cent. of sand in the discharge is more usual. This you will notice is from three to four times as efficient as the ordinary form of dredge. The reasons for such a large increase in efficiency are evident at a glance. The suction end of the pipe is no longer left to the freedom of its own will. It is under the absolute control of the dredge master. It cannot balk or shirk its work; the hopper discharges betray its every failure. Anything in the way of free materials, sand, mud, gravel, even clay, that comes in way of the ponderous head has to come up. If the ground is soft, it is immediately responsive; if there is an incrusted surface, as there often is with sand, it is immediately destroyed by a furious application of water jets controlled by the dredge master, which issue from and into the head in a veritable maelstrom, the result reminding one of hydraulic mining as practised in the west, or the Seattle habit of sluicing their hillsides around the town. It is precisely the same principle, with precisely the same results. No material but solid rock can withstand the pressure of the water jets, and in the Fruhling head there is, in addition, a great plow or rake that cannot be resisted, while the pump suctions finish the work.

The first real Fruhling dredge—*i. e.*, not experimental—was the "Nicolaus," built for the German government for use at the Elbe entrance to the Kiel Canal. The Elbe is of the same nature as the Delaware; it deposits mud, in places where it is particularly undesirable, in unlimited quantities. Big bucket ladder dredges and a fleet of steam hoppers could not keep down the deposits, which threatened to choke the whole canal entrance. With length of only 153 feet, a hopper capacity of only 520 cubic yards, and a single 16-inch centrifugal, the "Nicolaus" clears up the mud and removes it two miles to dump at the rate of 6000 cubic yards in the ten-hour day. The 520 cubic yards can be filled in from twelve to fifteen minutes, giving a pumping capacity per hour of nearly 1500 cubic yards after deducting percentages for water contained in material and in the hopper. The percentages of solids pumped vary from 80 to 90 per cent., the bottom being thin, soupy mud. Such results were simply a revelation, and created new records in suction dredge work.

They are recorded in the following certificate from the late Herr Scholer, Chief Engineer on the Kiel Canal:

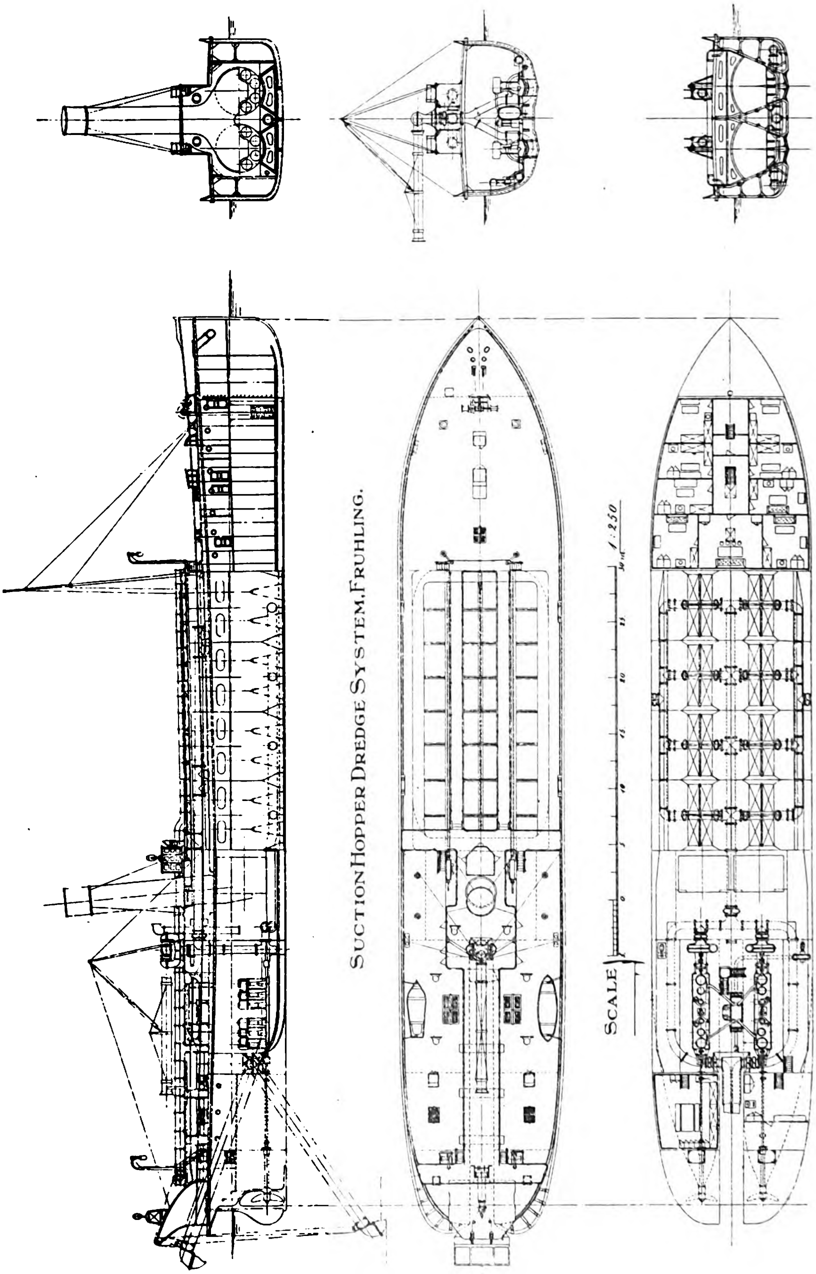


Fig. 4.—Profile and Deck Plans of Fruhling Dredge for Imperial German Navy.

"This is to certify that the dredge 'Nicolaus,' in the Emperor William Canal, has dredged in 700 working hours 1,350,000 tons of sand, mud, and silt, and has transported and discharged this material for a distance of 1.5 miles in 1450 hours. The average cost of the above work (including transport) was three-fifths of a penny per ton (1.2 cents).

"After carefully watching the work done by the 'Nicolaus' I am able to say that, in my opinion, the Fruhling system is the most reliable, economical, and effective system of maintenance dredging I have seen.

(Signed) "SCHOLER,
"*Chief Engineer of the German Government of Kiel Canal.*"

The Fruhling dredge is the maintenance dredge *par excellence.* It is a marine channel scraper, or, to use another simile, a submarine vacuum cleaner, and it clears the channel as fair and true as a plane leaves a plank. It cannot cut holes and overdepths and it cannot undermine banks and quays by ill regulated suction effects outside of the head, because there are none.

The success of the "Nicolaus" was so pronounced that it resulted in an order from the German government for one of the largest and most powerful suction dredges that had been built to that date. See Figs. 2 and 4. This dredge, known as No. VII, was required for the cutting out of the great North Sea Naval Station of Wilhelmhaven, which now harbors the German North Sea fleets. It is a 2000-yard hopper dredge with two 24-inch centrifugal pumps, 2000 I. H. P. engines, and a speed when loaded of ten knots. The pumping capacity in mud was found to be over 5000 cubic yards per hour, and in sand over 2000 cubic yards. Such a demonstration of efficiency in rough sandy ground had not previously been approached. It may be said that this large type had to carry its hopper load more than 8 miles to dump, but owing to the saving of time in pumping a load, it was able to do so at a marvelously low cost rate.

Orders have been executed recently for Fruhling dredges for Germany, England, China, Japan, Canada, Belgium, and the International Danube Commission. Brief reference will be made to the Belgian and the Danube Commission's vessels, which are among those most recently constructed, and which illustrate further developments in the Fruhling system. The method in common use on the Delaware is to dump the dredgings from scows and dredge hoppers into the river and to re-pump again by a pipe line dredge on to the shore behind bulkheads, and thus to utilize the dredgings for

land reclamation, and incidentally to get rid of the material dredged once and for all. Herr Fruhling too had to do this work in the Kiel Canal, but it did not appeal to him to dump back into the water the dredgings already secured, and then to employ another dredge to lift the dredgings again over the embankment; in fact, this is a hopelessly wasteful, expensive, and inefficient plan, with nothing to commend it.

To get over the difficulty a hopper suction self-discharging arrangement was designed. This consists of a central hopper pipe concealed in a hollow girder over the keel with inlet branches to the hopper. Means are also provided for admitting outside water to dilute the hopper contents if they become too dry to pump after standing, and also to blow away with water jets under pressure any block of material which might choke the suction pipes. The hopper contents are thus easily sucked back from the hopper pockets with the dredge pumps and discharged overboard through a deck pipe connected temporarily to a pipe line erected on the quay alongside or on a trestle work or temporary piling. In this way no material is lost by dumping back into the river, no rehandling dredge is needed, and with mud the discharge is exceedingly rapid, rarely requiring more than the period taken to load, say, from fifteen to twenty minutes. In designing the Belgian dredge, which had to operate exclusively in mud, it was decided to unload by pumping only, and the hopper bottom doors were omitted; this seemed at first a somewhat bold step, but it has since been noted that, as an incidental result, a gain in efficiency of from 10 to 15 per cent. has been obtained. This is due to the fact that the bottom being water-tight, which hopper doors never are, no deduction has to be made in calculating the hopper contents for the water entering the hopper after load is dumped. The pumps therefore discharge into a practically dry hopper and there is no dilution by water in the hopper.

The International Danube Commission ordered a large vessel 230 feet long, 1300 cubic yards hopper capacity, two 24-inch centrifugals; this vessel had to work alongside one of the most powerful bucket ladder dredges in existence, which was, after the arrival of the Fruhling dredge (which could deal with all the sand and mud), relegated to the dredging of clay and other materials not usually considered hopper suction dredge work. As, however, banks of clay ran through the sand and mud, it was decided to try the "Dimitri Stourdza," as the dredge was called, in this material. After numer-

ous experiments involving various changes in the dredge head, a form was obtained which enabled the clay to be handled at a rate exceeding the best results of the bucket ladder vessel. The form of head was narrower than usual, perfectly smooth in the interior, studded full of pressure water-holes to form lubricating areas, and with guard plates and suction jets over the suction exits from head to prevent choking at this place.

This description of the Fruhling system has failed if the members of this society have not been impressed with the possibilities of the dredge at Philadelphia. What, in a word, is the situation which confronts Philadelphia as regards the Delaware River channel? It is safe to say that a 30-foot channel from Philadelphia to the sea is no small achievement, and reflects credit on the men who planned it and the contractors who executed the work. But the question is, Where is the 30-foot channel? The answer appears to be that it no longer exists; in fact, Philadelphia's great trade route is threatened; its commercial throat is in the grip of an insidious enemy, the well-known "mud-devil." It will surely not take reports of many more strandings of transports, battle-ships, or ordinary tramps to convince one that something is seriously wrong. The report of the army engineers on the proposed 35-foot project must convince any one that such is the case. The channel of the Delaware is exposed to rapid deterioration by the formation of mud shoals of enormous extent from which relief is only obtained by costly dredging; diking the channel is simply out of the question. Money which might be used for increasing the depth of the channel must be spent to secure a precarious hold on what depth there is now—a hold so precarious that there is uncertainty of even retaining it. Instead of having 30 feet of depth at low water, it does not now appear certain that there is a depth of 24 feet. The situation is serious, and calls for immediate treatment. Can any port prosper when it is falling rapidly behind neighboring ports in its ability to handle ordinary sizes of modern tramps, not to speak of the liner or the battle-ship? This, in a word, is the question facing Philadelphia to-day, and reference is made to it only because there is a solution to the problem of channel maintenance in the Delaware River.

There are two features to this problem:

1st, The lifting of the material from the channel.

2d, The disposal of the material after lifting.

As regards the first feature, it may be said that it is a matter of

national importance, and must be faced in a large and broad-gaged way. A scraper must be put through the channel, not once or twice, but all the time, and it may be for all time, and that scraper must be large and powerful, and it must be ready to do its work anywhere. Such a scraper will be found in a Fruhling dredge.

As regards the disposal of the dredged material, that is a problem of great importance. But too much has been made of the necessity, on maintenance work, of putting the dredgings ashore. If artificial fills are not available within reasonable distance, it is absurd to waste time in running to distant dumps when the one thing needful is to clear the channel. Therefore, let it be supposed that a shoal has formed in some part of the channel. Attack it with a Fruhling scraper, loading into the hopper, but steam only as far from channel as shoal water will admit; then discharge by bottom door or by overboard pumping, while paying reasonable attention to tidal flow and set of currents. No one will deny that much of the dredgings will go back utlimately into the channel,—that is inevitable; but in the meantime the channel depth is maintained by an appliance of such tremendous power as will quickly get it clear.

DISCUSSION.

R. Schmitz.—The Fruhling system of dredging has many advantages, undoubtedly. I can see where it is probably the best in canal work or in channels that are limited in depth, but for the Delaware work I can hardly see that it has the advantage that a system of tugs and scows would have in connection with the form of suction dredging discussed this evening. If we consider that the average distance from the channel to be dredged in the Delaware out to sea is probably sixty miles, and if we add to that, say, five or ten miles further out to sea, making perhaps 55 to 70 miles, you can readily see that perhaps 75 per cent. or more of the time of this boat would be occupied in travel, and not in actual work.

On the other hand, if we take such a boat as this, or perhaps one of smaller capacity and therefore less cost, and add to it a plant of tugs and scows of probably two or three times the cost of the smaller boat, we would have a plant costing probably two or three times as much as a boat of the larger size of this type would cost. Such a plant would probably be able to take ten times as much material to sea as a boat of this character would alone. In the case of the Delaware, the length of haul is the deciding factor. I can see easily where a short haul is of great advantage to a boat of this class. Experience has shown that the dumping of material in the Delaware—and probably in a great many other rivers in the United States)—outside of the limits of the channel, is detrimental in a short time. Much of the river bottom adjoining the channel has a slope of perhaps 1 in 20, or 1 in 40, or 1 in 60. The material dumped out of scows of this character is soft, like soup, and therefore will flatten out quickly, almost as soon as it is dumped into the river, and is again taken up by the current and in a short time is in the same old place.

So that this experience has led to the passing of laws which make it a misdemeanor to deposit any material within the high-water mark of the Delaware or any navigable river; even the dumping of ashes from tug-boats is prohibited by law. There is good reason for this, and the mere suggestion of adopting a plant of this kind to clear the Delaware would, I fear, meet with strong opposition by people who have made these discoveries from long experience.

By the improvement of the Philadelphia harbor some ten or fifteen years ago there was deposited north of the present Delaware River bridge of the Pennsylvania Railroad, in what was considered a pocket between the Jersey shore and the other side, a very hard sand or gravel; it was poured some distance from the Jersey shore, and in this pocket the water was considerably deeper than it was on the bar. Still, with this advantage in favor of the dump, it was only a short time before a survey showed that the material was no longer there, and the question arose, where was it? The channel shoaled up, and there is no doubt but what a great deal of it found its way back to the channel. Of course, no one could prove that this was precisely the same material, but the fact remains that the channel shoaled up.

Therefore, the standard of economy seems to be to adopt a dredge of this class, to use the very good suction appliance that this dredge possesses, and deposit the material thus sucked up into scows of large capacity, say perhaps a thousand yards apiece. Again, to have a sufficient number of scows to keep the dredge practically busy during twenty-four hours, which would mean in addition a tug-boat plant of probably two, four, or six boats, depending upon the size of the dredge. Of course, the relative proportions can be worked out by taking into consideration the time in which the tug-boat would be able to return with its tow of scows and the amount of material the dredge could take out when working constantly during twenty-four hours.

I suppose no one will doubt that the greatest economy in an operation of this kind is produced when the machinery is constantly in operation. The interest on the money invested continues day and night and Sundays, and the expense of additional forces required to operate a dredge at night, or on different shifts, is not sufficiently great to overbalance the interest loss or time loss if the plant is operated only a part of the twenty-four hours. It will take perhaps two tides, or may be three tides, to deposit the material for a distance of 60 or 70 miles, the tug-boats working with the tide, taking a long tow and going down-stream with the tide on the ebb, and coming back afterward on the flood tide with the light scows, which has been found to be a great advantage in a tidal river.

E. H. Rigg.—I cannot claim to be a dredge specialist, and in these days of specialization the outsider has to be careful how he trespasses on another man's ground.

From the paper, data, and pictures there is no doubt as to the efficiency of the Fruhling head, and the simplicity of the idea goes far to establish its claim.

In a recent issue of "International Marine Engineering," a series of articles on dredges appeared, so that this paper has been read at an opportune time; but, more important still, several meetings have been held in this city lately to urge a 35-foot channel for the Delaware. The latest battle-ships draw close to 30 feet in salt water, and well over that figure in fresh water, to say nothing of any extra draft caused by damage received in action; how, then, could a damaged "Florida"

get to the Philadelphia Navy Yard, through a channel barely 30 feet deep, even with the additional water due to the tide? An important harbor should be approachable at all stages of the tide, and Philadelphia is at present not in that enviable position, even as regards quite ordinary merchant steamers, let alone our new battle-ships.

The gentleman who spoke before me suggested that it would not be economical to run these dredges to a distant discharging ground; it should not be difficult to figure out when it will pay to let the dredge discharge itself, and when it will be necessary to carry the spoil by other vessels; it is a matter of distance and the time your expensive dredging plant is necessarily idle. The plan advanced by Mr. Reid of building the dredge with no bottom doors, using the pumps for unloading as well as loading, is most ingenious, and very well adapted for land reclamation work; it also is a good reason for letting the dredge do its own carrying and discharging.

Mr. Schmitz commended the scheme of scows and tugs, drifting with a fair tide and anchoring when the tide is foul. I venture to suggest that steam hopper barges would do this work more economically, because the argument in favor of the scows (that the tugs are not idle, as they can drop a train of empty scows and pick up a train of full ones right away) does not hold good when the outfit is anchored during a foul tide. The hopper barges I have in mind could be designed to carry some 4000 cubic yards, and be provided with their own propelling machinery; they could each tow one hopper scow of their own size, if desirable. Such boats would be of moderate draft, say, some 18 feet, and proceed independently of tide. The necessary crew would be very little, if any, larger than the tug and scow crews. The self-discharging dredge is to be preferred, however, except for very long hauls. The steam hopper barges are used extensively on the Clyde, in channel improvement and maintenance work, which involves a long haul.

Mr. Reid's latest design involves another feature that is unusual in dredge designs; he couples the dredging engines up with the propelling engines, and thus gets more power on the propellers. The advantage is dependent on three things: viz., whether the distance to depositing grounds is enough to justify coupling up; whether the depth of water is enough for an appreciable increase in speed to be gained; and whether the propeller can be designed to be efficient at the low speed of the dredge and the comparatively high number of revolutions at which these engines work. The first two are beyond the control of the dredge designer, but I think the third can be successfully met, on account of the big improvements recently brought about in propeller design, following the introduction of steam turbines for marine work. Another great point in favor of this dredge, in common with all suction dredges, is its ability to undertake long ocean voyages. Bucket ladder dredges have gone to sea and never been heard of again. These vessels can be built in the United States and delivered in China or the Philippines, carrying their hoppers full of coal for the voyage, all without undertaking any undue marine risks.

Mr. Schmitz.—In reference to the work at harbor mouths, a dredge of this kind is probably as economical as we can get, because you are close to the dumping grounds and the haul is short, which is not the case in the Delaware. There is deep water for perhaps 50 miles, or nearly so, from the Capes up the Delaware River, deep enough for the deepest draft vessels at the present time. As I said

before, it is a long haul in the case of the Delaware River—70 miles—which would mean that it would take a tug-boat say half an hour to load and a day to make the trip, which shows a loss in the use of the plant.

On the other hand, the use of steam hoppers, which was suggested as being economical—more so than scows—would make it necessary to use a crew for each boat, which means an engineer, a fireman, a captain, probably a mate and a deck hand or two, a cook, and others, while in the case of a tug-boat it would require only one crew which can haul five to ten times the amount of material that one of these hoppers can haul. It would probably result in less speed, but not as little as one-fifth of the speed, and considerably more than one-fifth of the speed of the other, and therefore would be more economical, saving the wear and tear and depreciation of the machinery of one of these steam hoppers compared with the scows, and their expense of operation and first cost would be greater.

A. M. LOUDENSLAGER.—When Mr. Taft, now President, came back from Panama, he made a very glowing report about the success of these dredges. I made some comparisons of that report and the performance of the present dredge now operated in the Delaware. Much to my surprise, upon taking up item for item, I found that the dredge "Delaware" was doing just as good work as was claimed to have been done in Panama.

A dredge was built in Philadelphia, and tested on the Delaware, which afterward made a trip of about 15,000 miles to the Columbia River, carrying its own coal.

The capacity of the dredge "Delaware" is about 3000 cubic yards, and we fill these bins in twenty-two minutes; that is, with mud and water; what percentage is mud is demonstrated afterward. We keep going continually; that is, say, we start out to-morrow (Sunday) night, and work twenty-four hours a day until next Saturday. If we had to haul, say, down to Ship John, 60 or 70 miles, it would be simply impossible to do this; we have to put the material ashore. It is necessary to have some sort of a re-handling plant or pumping machine which will lift the mud and take it away, after it is taken out of the channel, and get it ashore.

MR. REID.—In regard to the clearing up of the Delaware, I do not want you to assume that I have but taken a look at the Delaware River from the quays, and that I am going to give you in five minutes a solution of a problem which has baffled the best talent in this country for many years. I have made myself familiar with the reports of Major Deakyne and others; the report of Major Deakyne is one of the most remarkable documents on dredging which I have seen up to the present date. Therefore I can talk with some authority on this subject.

I agree with your President that there is no necessity to tow the material 70 or 80 miles to sea, and you would not think of towing it with a Fruhling dredge, or any other dredge; there are many Delaware fills that have been built, and I know that you have many artificial fills into which you can pump dredgings, if you have the machinery.

The "Delaware" is a splendid dredge, but she cannot get the stuff out of her hopper again, except by dumping. The Fruhling dredge pumps her stuff out alongside of the fill. Where there is a channel with millions of cubic yards of mud in it, the main thing is to get it out as soon as possible. You must get the mud

out, and it does not matter whether you put it on the bank or a few hundred yards out of the channel.

I saw the "Delaware;" it is a splendid dredge. In the Ambrose Channel four of the same type have taken up at least 40,000,000 yards. Material of all kinds has been lifted, carried to sea, and dumped. But when you are going to dredge out a channel like the Delaware River, that type is worth nothing; it is no mud dredge. I can give you the proof. On the Panama Canal some of the dredges are absolute duplicates of the "Delaware." They are the dredges which Mr. Maltby described to this Society. Mr. Maltby and I proposed converting them into Fruhling dredges; Col. Goethals proposed the same thing; but the money was not forthcoming to do it. One of those dredges went down to Colon, and here is the result: In mud she could not fill her two-thousand yard bin with 800 cubic yards after pumping for an hour, and had therefore to go to sea with her hopper but one-third full.

That is to say, you have a tool that is supposed to lift 2000 cubic yards, but she has to go to sea with 700 or 800 cubic yards because the water takes the rest out with the overflow. You have to get rid of the water and get your hopper filled with thick stuff. In the Fruhling dredge you pump from the inside of the head; the stuff is thick, and not "soup" as the gentleman here said a moment ago.

The "Clapsop" made a splendid trip to the Columbia River, and our dredge "Fruhling" made a similar trip to the Frazer River, B. C. The "Clapsop" is of the same capacity hopper, and loads about 800 cubic yards sand in about one and a half hours; our dredge loads the same in about thirty minutes.

We have arranged with Major Deakyne and the Department at Washington to build for the army the largest dredge which has ever been contracted for in this country; 3000 cubic yards capacity, 300 feet long, 20 feet draft of water, for use in the Mississippi River. She is supposed to lift 5000 cubic yards of mud per hour, and if she does not do more, I shall be disappointed.

PAPER NO. 1088.

AN AUTOMATIC SIGNAL FOR ELECTRIC RAILWAYS.

CARL P. NACHOD.
(Active Member.)

Read May 21, 1910.

IN track circuit signaling for steam roads it is usual to place the signal indication, as the semaphore, at the insulated track section, which is the beginning of the block. The engineman of the train enters the block if the signal shows clear, and does not look behind him after passing to see that it has gone to danger to protect the rear of his train. Such a signal indication would ordinarily be a two-position one, in which the absence of the danger signal constitutes the safety signal. The apparatus to work in this manner must be of the most perfect design possible and the inspection and maintenance of the same quite thorough and expensive. In fact, a report recently made public shows that on a road having over 100 semaphore signals the maintenance has figured about $100 per signal per year.

These signals are operated from a track circuit in which the only insulation between the two rails is that of the wood ties and ballast. The pairs of rails are separated into signaling blocks by means of insulated joints. At one end of the block there is connected a relay consisting of an electromagnet with an armature which, when attracted against gravity, holds a pair of contacts closed. At the other end of the block a low voltage battery, two gravity cells in parallel, is connected across the two rails. There is thus a closed circuit formed through the rails, the battery, and the relay magnet, the rails being of opposite polarity. The relay magnet is continuously energized when the block is clear, that is, with no train on it. In the circuit of the relay contacts is the signal-indicating mechanism, operated by an independent local battery, the mechanism being arranged so that the signal indicates clear only when current flows in the circuit, and drops to the danger indication when this circuit is interrupted. When a train enters the insulated track section, the train wheels form a shunt path of very low resistance relative to that of the relay magnet, which is therefore deprived of current and drops

its armature. The contacts being opened, current is interrupted in the local circuit and the signal goes to danger.

The track circuit system is quite ideally safe; for a failure of the circuit caused by a broken rail or wire, or a battery failure, will give a danger signal; and even switches may be interlocked with the track circuit, so that, when misplaced, they will short-circuit the rails in the same way as a pair of wheels. Fig. 1 shows the connections for this elementary track circuit.

In the case of electric railways where the rails are used for the return of the propulsion current, the track circuit may not be used

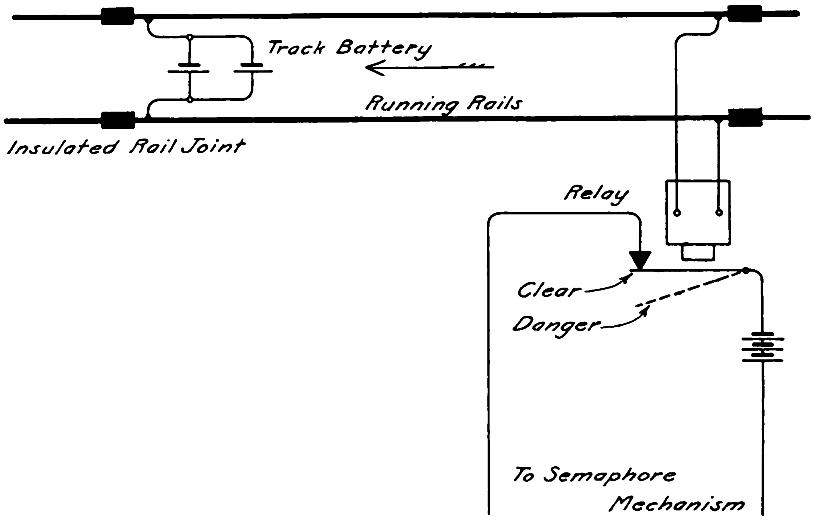


Fig. 1.—Essential Diagram of Track Circuit.

in so simple a manner. For these, alternating current from separate mains may be applied to the rails for signaling, and caused to act selectively on a suitably designed relay. Track circuit signaling for electric railways is quite complicated, and even more expensive than for steam railways, with no increase in reliability to compensate.

In the system to be described the signals are caused to be displayed not by means of continuous track circuit, which indicates by the actual presence of the train, but by the car or train having passed definite points where contact devices are located. It has been a difficult matter to design a contact-maker that would operate with certainty at any speed, but by incorporating a feature not generally

used on steam roads, an equivalent safety can be produced by well-designed contact devices, resulting in a much simpler signal installation.

The system brought to your attention is intended to prevent head-on collisions on single-track electric railways where cars run both ways on the single track. It has three indications: neutral, proceed, and stop. The neutral—meaning, presumably, clear—may be changed to proceed in the sight of the motorman after he passes the contact device and before passing the signal indication. He therefore becomes responsible for setting his own signal and does not proceed until he is aware that he has set it. With this arrangement the signal indication must be set a sufficient distance ahead of the contact device to enable the motorman to see the indication both before and after passing the contact device.

The electric circuit of the permissive or proceed indication is completed through that of the danger or stop indication in the distant box, and the display of the former is therefore an assurance that the latter, the main signal, is displayed.

When the motorman approaches the single-track block from a siding or turnout, he observes the signal indication before reaching the trolley contact switch. If this is neutral, it means that the block is clear. After running under the contact switch he observes the change made by his car in passing it, and if the permissive signal shows, he passes the box and enters the block. The permissive or proceed indication is given by an opaque white color disk and a white light at the same time, making a combined day and night indication. While a semaphore, which is an arm pivoted so as to show sharply defined positions against the sky, is probably the best signal aspect as regards visibility, it is not used in this case because it is too vulnerable for any but private right of way; and besides it requires an excess power to drive, on account of rust, snow, and ice due to exposure to the elements. The day signal is therefore an enameled aluminum disk adapted to be withdrawn or exhibited before a glazed opening in the signal box. When the motorman sees the permissive signal, a white light and a white disk, he knows that the danger signal at the other end of the block is showing to prevent a car from entering against him. This signal also consists of a red light and a red disk displayed simultaneously. An electric light alone for a day indication is unreliable, for with a combination of low voltage and direct sunlight it is almost indistinguishable. But the conditions that are

against the light are all the more favorable for the disk. The signals being set remain until the car reaches the other end of the block, when in leaving it runs under another contact switch so as to clear or restore them to the normal neutral indication.

If, however, before the car leaves the block a following car should arrive at the turnout, the motorman of the latter car will see the permissive signal and will proceed into the block at limited speed expecting to find a car ahead of him. As he runs under the contact switch there will be a flash or blink of the white light caused by the passage of his car, which serves as evidence that his car is counted in or recorded in the signal relay. When the first car leaves the block, it will not restore the signals to normal, but these will be held until the second car leaves also. Where several cars may follow into the same block it is termed permissive block signaling as against absolute, where but one car may enter the block, setting stop signals at each end of it. For electric railways where the blocks are long and where there is at times a preponderance of travel in one direction, the permissive operation is most convenient.

If a car should enter the block, setting the signals, and back out again by the other track at the same end of the block, using the single track merely as a Y or cross-over, the signals will be automatically cleared on the exit of the car. This makes a very flexible operation; for instance, cars entering the block from one end may leave by either or both ends, and the signals will be held permissive at one end and danger at the other until all the cars have vacated the block.

So long as the red signal shows, the entering switch at that end of the block is "dead" or cut out of operation, and a car running under this switch accidentally or otherwise will cause no change in the signals. Thus if a motorman should violate the red signal and enter the block against it, causing a head-on collision, the signals will remain as evidence against him. Should he have been able to clear or change the signals in wrongly entering, there would arise a question of veracity, rendering the signals valueless. A more important use of the lock-out feature, however, is where two cars attempt to enter the block from opposite ends; one reaches the switch a moment before the other; the first car, obtaining the permissive signal, goes ahead, while the motorman of the second, seeing the red flash up before him, but being too near to stop his car, runs under and backs out again as soon as possible. Both passages of his car under the trolley

switch cause no change in the signals, since the trolley switch is "dead."

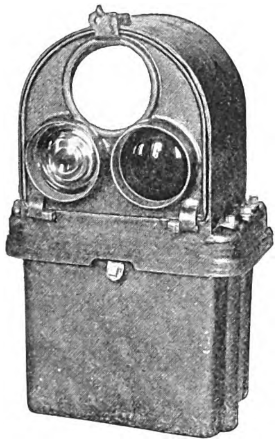


FIG. 2.—Signal Box, White Semaphore Indication.

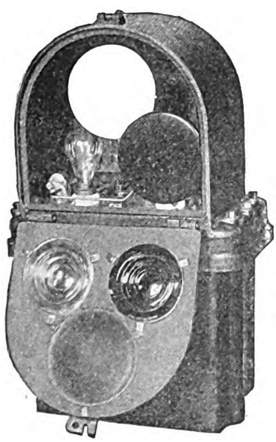


FIG. 3.—Signal Box with Front down, Showing Semaphore Disks, White Indicating, and Giving Access to Lamps.

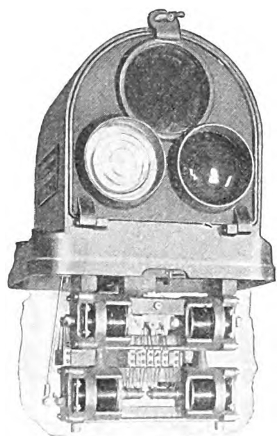


FIG. 4.—Signal Box with Oil Tank Removed, Exposing Relay, Red Semaphore Indicating.

In the very rare case where two cars, running in opposite directions, reach the switches at exactly the same instant, no permissive signal would be obtained by either, and each would back to the trolley

7

switch again, the one first reaching it setting the signals, cutting out and holding up the other car.

The burning out of any lamp will not cause a false safety indication, even though the independent day signal, which will not be affected, be ignored. The relay magnet positions will be assumed regardless of the lamps, which are only indicators of these positions. Furthermore, on the resumption of power after its failure, the signals reappear, indicating the same as before.

The signal may also be used as an absolute block system. For instance, suppose a work train enters the block, the intention being to close the block at both ends. The motorman opens the hand clearing switch, located on the same pole with the signal box, which is equivalent to opening the line wire. In this condition the signals will remain neutral and no proceed indication can be gotten from either end. To restore the system to permissive operation again, this switch must be closed on leaving.

The threefold signal mechanism comprises the indicating, or the colored lights and disks; the intermediate or relay; and the actuating, or the trolley contact switch.

The signal aspect is given by three openings in the signal box (Figs. 2, 3, and 4), through the upper of which, one or the other, the red or white color disk, shows when the signal is set, and a void when clear. The lower openings have a clear and a red semaphore lens respectively, behind which are incandescent lights, the disk that is not indicating being used as a screen for the other lens. The opaque color disks are mounted on levers, counterweighted so as to assume the indicating position by gravity, and actuated by the magnets of the relay below, being driven by push rods, so that there is no shock transmitted to the disks by the quick motion of the magnets. Fig. 5 shows this connection.

The relay, which translates the impulses of current caused by the passage of the wheel on the contact device into signal indications, is a unit, shown in the lower part of Figs. 4 and 5, made up of a number of iron-clad stopped plunger type of electromagnets assembled on a contact board. These magnets carry plungers having metallic contact rings supported by insulation. Spring fingers press against the rings, and connection between the fingers is made or broken according to the position of the plunger. The counting means is a magnet-driven ratchet wheel and pawl, carrying a revolving switch, and arranged with a positive stop so that it is impossible to pass more

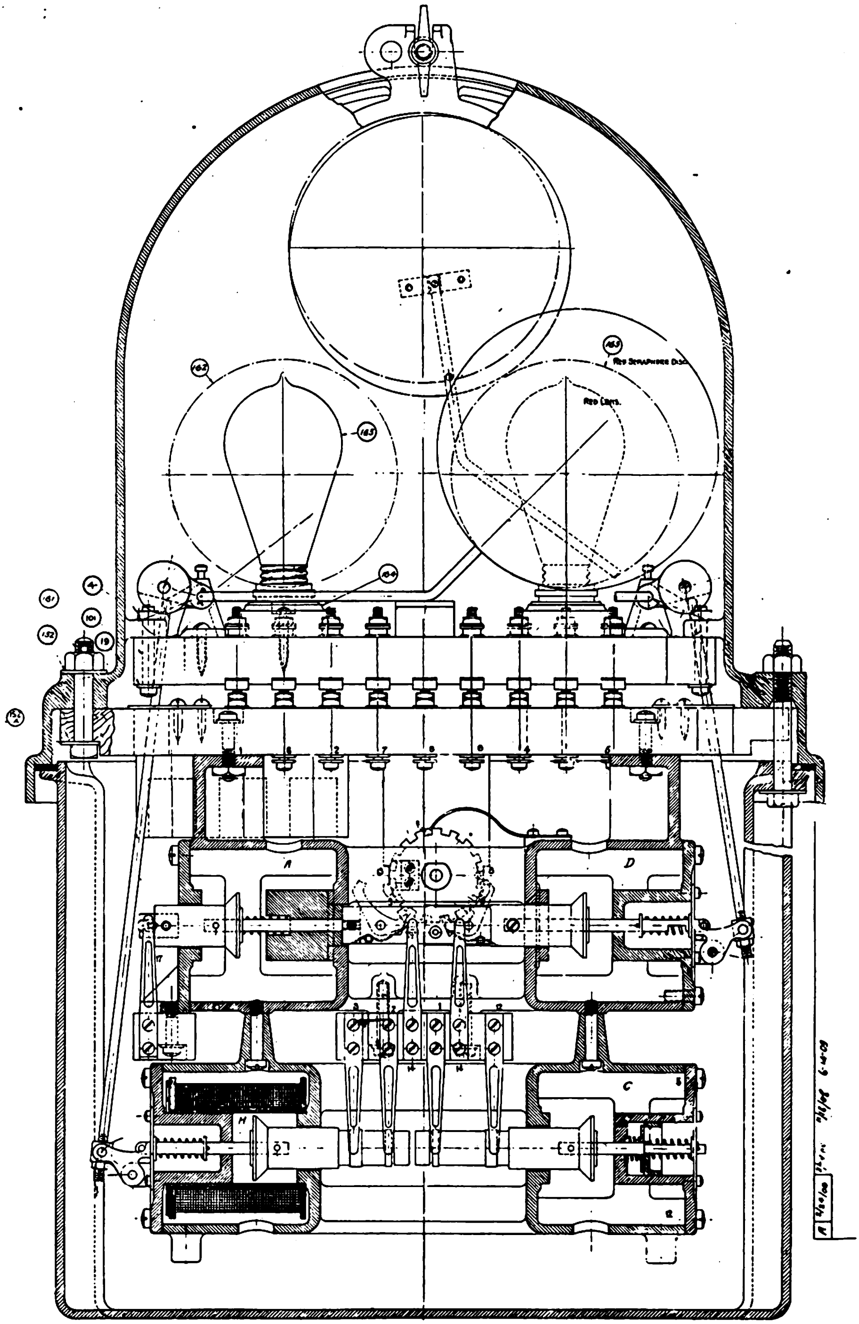


FIG. 5.—Elevation of Signal Box.

than one tooth at a time. Each of the magnet circuits is so designed that a powerful current starts the movement of the plunger, this current being automatically reduced to a safe value either by inserting resistance into its circuit or shunting current around it when the plunger is nearly seated. The connecting leads are brought to contact studs at the top of the relay, and the entire relay is hung from

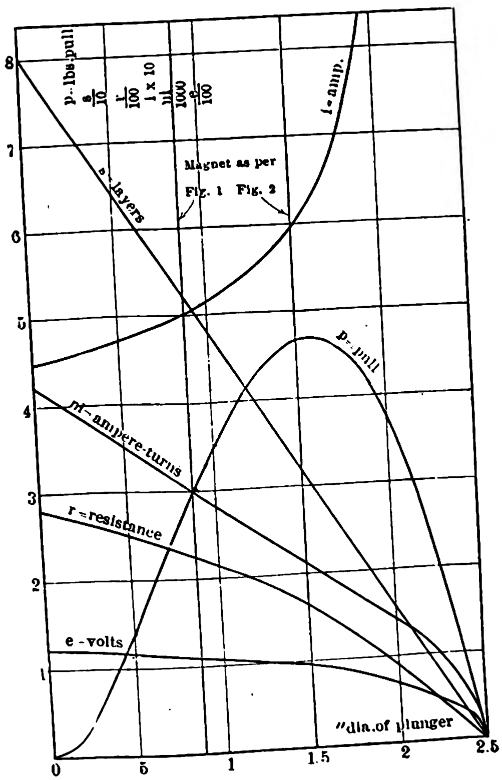


Fig. 6.—Curves of Magnet Design.

the upper case, so that connection is made automatically through spring contacts to the incoming leads and lamps above. Thus a damaged relay can be very quickly replaced by a duplicate without disturbing the wiring in any way. The type of electromagnet with the mushroom-shaped armature as shown in Fig. 5, is somewhat unusual, and was developed by the author after some investigation.*

* Electrical World, Sept. 21, 1907, p. 563; Sept. 30, 1909, p. 768.

The curve p in Fig. 6 shows the variation of magnetic pull with diameter of pole face for magnets of the same type, having the same external dimensions, stroke, and heat loss in the coil. The rectilinear motion of the plunger is well adapted for making contact by sliding, and the bearing surface and consequent durability of such a plunger magnet is much greater than that of the pivoted armature type.

The entire relay, including both switches and coils, is immersed in oil in a tank which hangs independently from the upper case. This is a construction new in signal work and conferring a number of benefits, among the mechanical ones being continuous lubrication of moving parts, the prevention of corrosion, and cushioning of the violent magnet blows. Electrically, the oil suppresses the arc at the contacts, keeps the coils cool so as to increase the range of current through which the relay is operative, obviates burn-outs, improves

Fig. 7.—Trolley Contact Switch from Above.

Fig. 8.—Trolley Contact Switch from Below.

the insulation of parts, permitting of a very compact design, since the live parts may be brought closer together than in air, and also minimizes damage by lightning.

The trolley switch (Figs. 7 and 8) consists of a light metal framework for holding two longitudinal inclined contact strips in such a relation to the wire that the wheel will touch the wire and one or both of the strips, which are electrically connected, but insulated from the trolley wire. The cold rolled steel contact strips are flexible in themselves and flexibly mounted through phosphor-bronze springs; but they are provided with positive stops to limit the deflection. It is a very delicate matter to attempt to restrain or touch the light trolley wheel moving at high speed, and the utmost flexibility of the contact-making device is requisite. When it is considered that a car running at 60 miles per hour will traverse a foot in approximately

consists of the hanging of two signal boxes on poles, and four trolley switches in the four branches leading to the single track, with the necessary taps to each.

In Fig. 9, which shows the signal in service, the car has entered the block of single track and is still in it, having disappeared beyond the bend, leaving the signal permissive for another car to follow. The clearing switch for this end of the block may be seen over the

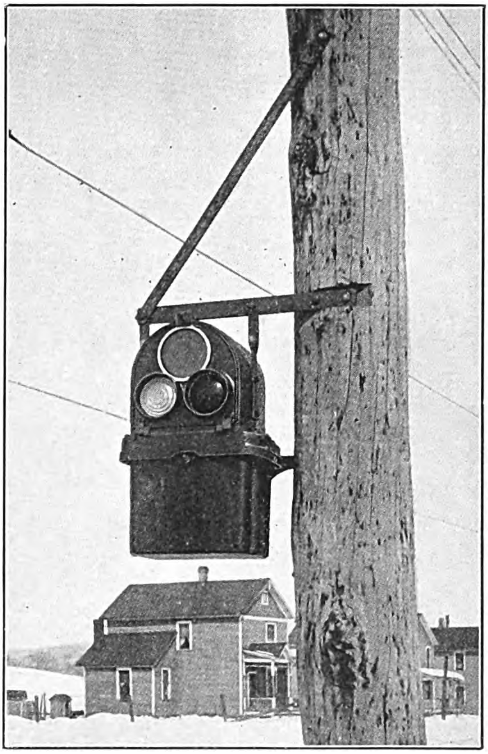


Fig. 10.—Mounting for Signal Box on Wood Pole.

turnout at the left. The box on the stub pole is a telephone system for emergencies. Fig. 10 shows one method of mounting the signal box on a wooden pole.

The electrical operation of the signal is shown in principle in Fig. 11, in which only the parts essential to a comprehension of the scheme are shown. These are in position for no car on the block, in which

case each end of the signal wire is grounded through a red lamp, R. With no current in the coils, armatures drop. The first entering car sends an impulse of current through magnet A in the relay at the entering end, operating a two-way revolving switch, which transfers that end of the signal wire to trolley through a white light, W, and a magnet, D. This light and the red one at the other end now burn in series through the signal wire. Successive following cars turn the revolving switch so that the contacts overlap further, but make no change in the electrical circuit. Each leaving car energizes magnet C to break temporarily the signal circuit at 9–1, permitting magnet D in the first relay to drop its armature and revolve the switch in the reverse direction. When the same number of impulses have been made on the magnet C as on A, that is, when all the cars that have entered the block have left it, the signals are cleared and the con-

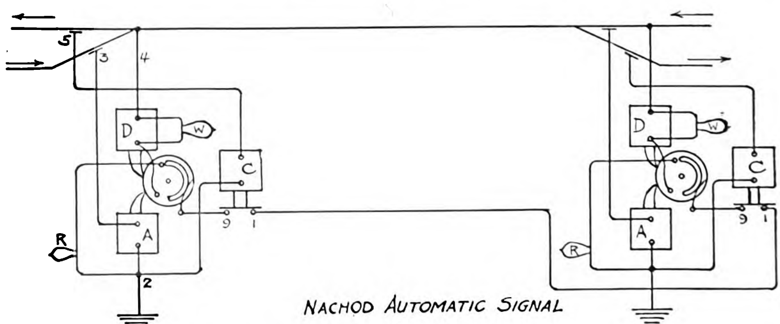


FIG. 11.—Diagram Showing Principle of Operation.

nections are as shown. The color disks are brought to an indicating position by magnets D and one in shunt with R not shown. A no-voltage magnet (not shown) is interlocked with magnet D in such a manner as to prevent a motion of the armature of the latter should the power fail with cars on the block.

In the foregoing description the trolley switches mentioned are not sensitive to direction of cars, and will cause the same result on the signal indications whichever way the car runs under them. Thus a car entering and backing under the same switch would set the signals as for two cars. The selection for direction can usually be attained by placing the trolley switches in the branches leading to the single track, so that cars run under each switch in only one direction, which will be the case if cars keep, say, always to the right. The use of two

trolley wires throughout, as is customary on some roads, is an advantage as giving a choice of location for the contact switches.

There are cases of car operation, however, where with D turnouts, *i. e.*, having one side of the turnout straight and the other offset, cars running either way will keep to the straight track if there is no car to be passed; and this will require a single switch that will set or clear the signal according to the direction of car. Fig. 12 shows diagrammatically a means of accomplishing this by dividing the contact strip longitudinally into halves. In conjunction with the reversing relays, this switch will act selectively to set or clear according to the end first reached by the wheel. Furthermore, by following out the

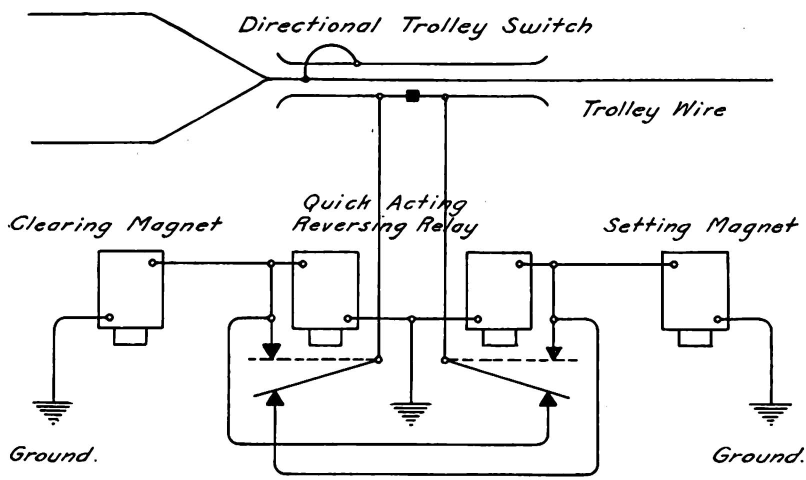


FIG. 12.—Connections for Directional Trolley Switch.

connections it can be seen that the total length of the switch—and not one-half only, as might appear at first sight—is utilized in forming the contact. The scheme is electrically analogous to having a finger hanging down over the wire struck by the trolley wheel so as to make either of two contacts according to direction of the car. It is, however, effected without moving parts in the contact switch, which, owing to its location, is not easily accessible for inspection and maintenance.

DISCUSSION.

E. J. DAUNER.—If the lamps should burn out at night, what provision is there for signalling?

MR. NACHOD.—Since the color disks and lamps are entirely independent, the disks would still indicate, and they could usually be seen by the headlight of the oncoming car. Supposing that the disks would not be visible at night, the system would then fail altogether, but could not be made to give false indications.

MR. DAUNER.—If the red lamp burns out, how is the system rendered safe?

MR. NACHOD.—In that case, although both permissive signals will be given, at the other end of the block the red disk will show. Should a car attempt to enter there, ignoring this indication, the entering switch is inert, the signals cannot be changed, and no permissive signal could be obtained by that car.

MR. DAUNER.—Suppose a work-train running irregularly should enter the block by the track against the customary direction of traffic; would the signals be properly displayed?

MR. NACHOD.—If the switch was directional, it would work properly; but if not, it would produce confusion. There may, of course, be two of these switches, one on each track, connected in multiple, so that the car entering under either of them would set the signal, and backing out under either of them would clear it. If the system were non-directional, the car entering and backing out under the same switch would leave the signal set for two cars. This may be corrected, however, by operating the hand clearing switch, located on the same pole, as many times as the car has made passages under the entering switch.

D. H. LOVELL.—Would it not be possible for a succession of cars going in one direction to be so spaced as to keep the signals set always in one direction, and therefore to hold up traffic in the other direction for a long time?

MR. NACHOD.—Such conditions are conceivable. They are covered by the operating rules of the road. This is an objection to permissive signaling which should not be used if the blocks are short.

RICHARD GILPIN.—What effect would lightning have, and do you find it necessary to use lightning arrestors or choke coils?

MR. NACHOD.—We require the installation of lightning arrestors spaced five to the mile on both trolley wire and signal line wire, and we have not found choke coils necessary. The oil immersion of the relay, by its high insulation, seems to protect the apparatus from injury by lightning. In case the relay is injured from this cause, it will be apparent in that if the stop signal does not set, neither can the permissive signal be set.

PRESIDENT EASBY.—Is it customary to inspect the signal systematically, and if so, what is the annual cost of doing so?

MR. NACHOD.—We have had reports of cases where nothing has been done to signals for more than a year at a time. Unfortunately, they often have to get along without regular inspection, but I think they ought to have a thorough inspection and test, say, every two months. We know that the oil does not evaporate, and that while it is there, the mechanism cannot rust. We have no figures on the cost of such inspection.

MR. LOVELL.—Could you incorporate an automatic stop if the motorman passed the stop signal, and where is the signal in operation?

MR. NACHOD.—One could probably be incorporated in the system, although we have not done so up to the present. For instance, there might be an electromagnet in the trolley switch which would throw the wheel from the wire when the car passes the stop signal. The signal is in operation in about thirteen differ-

ent places in the United States; as far out as Spokane, Washington; Los Angeles, California; Chattanooga, Tenn.; Chicago; Youngstown, Ohio; in Orange, N. J., it is used by the Public Service Railway Company; in Waterville, Maine, and a number of other places. In Philadelphia the Rapid Transit Company has adopted a similar switch at the entrance of the subway.

Mr. Gilpin.—I should think on account of the extreme flexibility of your switch that the weight of great accumulations of sleet in a storm might render it inoperative.

Mr. Nachod.—Ice is an insulator, and if the contact strips are partly covered with sleet it is possible for multiple operations to be recorded; but if the switch is entirely covered with sleet, then no contact can be made and no permissive signal can be given.

Mr. Gilpin.—No; but I mean would the weight of the sleet bend the strips so as to short-circuit the switch?

Mr. Nachod.—I think the trolley wire itself would hardly stand such an accumulation, and would probably be down before that time. At any rate, the switch has positive stops at the end to limit its deflection.

J. C. Trautwine, 3d.—What would happen if the insulation on the trolley switch should break down and the switch should be short-circuited?

Mr. Nachod.—If it were the setting switch, the signals would stay set for one direction and could not be cleared. If it were the clearing switch, the signals could not be set at all from either end. It is equivalent to opening the line wire, or the line wire breaking.

IN MEMORIAM.*

JOHN HEMAN CONVERSE.

DIED MAY 3, 1910.

John Heman Converse, the fourth child of the Rev. John K. Converse, was born December 2, 1840, in Burlington, Vermont.

For three years after his graduation from the University of Vermont, in 1861, he was connected with the editorial staff of the Burlington "Daily and Weekly Times." He then entered the employ of the Chicago and Northwestern Railroad Company, and thus became associated with interests which ultimately shaped his business career. In 1866 he accepted a position with the Pennsylvania Railroad Company under Dr. Edward H. Williams, who shortly thereafter became one of the proprietors of the Baldwin Locomotive Works of Philadelphia. In 1870 Mr. Converse left the railroad company to accept a position offered him by Dr. Williams, and in 1873 became one of the members of the firm of Burnham, Parry, Williams & Co., the owners of the Baldwin Locomotive Works. His influence rapidly broadened until he became one of the most conspicuous personalities connected with the manufacture of locomotives throughout the world. Hence when the Baldwin Locomotive Works were incorporated, July 1, 1909, it was but a fitting step for Mr. Converse to assume the presidency.

For many years Mr. Converse has been regarded as a financial authority of this city, and he has served on the Board of Directors of the Philadelphia National Bank, the Franklin National Bank, the Philadelphia Trust Company, the Real Estate Trust Company, and the Philadelphia Saving Fund.

Notwithstanding the work and responsibility demanded by his business enterprises, Mr. Converse devoted both time and means to many associations of an altruistic nature, including the Girard Estate, the Fairmount Park Association, the Presbyterian Hospital, Pennsylvania Academy of the Fine Arts, and the University Extension Association. He was for many years a member of the Union

* Memorial prepared by Grafton Greenough and James Christie.

League, and since 1884 has been a member of the Engineers' Club of Philadelphia.

No synopsis of the activities of Mr. Converse would be complete that did not refer to his continued and earnest devotion to the Presbyterian Church, of which body he was a member and in the councils of which he rose to a prominence paralleling his attainments in business pursuits.

In 1873 Mr. Converse married Elizabeth Perkins Thompson, of New York. He leaves one son and two daughters, also an adopted daughter, his wife having died in 1907.

While the foregoing incomplete summary of his numerous affiliations apparently precludes the idea of repose, Mr. Converse always seemed to have time to spare, and none who sought his counsel was ever turned away unheard. Though modest and unassuming in manner, he was firm as a rock in maintaining his convictions, and although his views might not coincide with those of others, he always impressed the persons with whom he came in contact of his earnest determination to obey the command "to do justly and to love mercy and to walk humbly with his God."

He was an untiring worker, and a practical optimist who had confidence in the future and believed in the ultimate advent of better conditions, and so he worked cheerfully and well.

The world has need of men like John Heman Converse. We revere his memory and realize with sorrow he is no longer here.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

Regular Meeting, April 16, 1910.—Present: President Easby, Vice-Presidents Christie, Hess, Hewitt, Directors Ehlers, Plack, Swaab, Hutchinson, Wood, Halstead, Worley, the Secretary, and the Treasurer. The minutes of the regular meeting of March 19th were read and approved, except that the loss on the restaurant reported by Mr. Christie to be $265.74 was ordered altered to $205.74.

Mr. Swaab was appointed a member of the Committees on Meetings and on Publicity.

The Treasurer announced that a note of $1500 had on March 29th been negotiated for a period of ninety days.

It was ruled that new members of the Club must have paid their initiation fees in order to be eligible to vote, although they need not have paid the current dues.

It was ordered that the Committee on Meetings be authorized to hold additional special meetings at their discretion, and thus test the sentiment of the membership at large toward the suitability of holding such meetings.

It was ordered that the Board meetings in the future be held on the Thursday of each month preceding the third Saturday, at 8 P. M.

The resignations of Charles Longstreth, Charles W. G. King, and Charles W. Lummis were accepted as of even date. The resignation of Charles H. Dading was accepted as of December 31, 1909.

The special committee appointed to devise ways and means for raising a fund for improving the Club-house presented a progress report.

Regular Meeting, May 19, 1910.—Present: President Easby, Vice-President Hess, Directors Ehlers, Cochrane, Plack, Swaab, Hutchinson, Mebus, Wood, Halstead, the Secretary, and the Treasurer. The minutes of the regular meeting of April 16th were read and approved.

The Treasurer presented the monthly report of the accountants, and also a brief report on the general financial condition of the Club.

Upon recommendation of the Trustees of the Bond Redemption Fund, it was ordered that the Trustees now cancel all bonds held by them, and that in the future all other bonds be cancelled as soon as they have been acquired.

Upon recommendation of the Committee on Membership, E. P. Dout, H. D. Elfreth, and R. P. Perkins were transferred from Junior to Active membership, and F. N. Price from Junior to Associate membership.

The resignations of H. S. Evans and D. M. Rice were accepted as of even date.

The following were elected as a Committee on Nominations to nominate officers of the Club for the year 1911:

Henry H. Quimby, *Chairman*,
Thos. C. McBride,
William C. Kerr,
Henry Leffmann,
W. B. Riegner,
John C. Parker,
E. M. Evans.

The Committee on devising ways and means for improving the Club-house presented its report, and, after discussion, it was ordered that the Board authorize the immediate obtaining of a loan of $8500 on a note secured by individual indorsements.

It was moved and carried that the $8500 loan provided for be expended in whole or as much as may be necessary for improvements, and that the amount of the loan be kept in a separate account, payments to be made on the architect's voucher and countersigned by the regular officials of the Club. It was ordered that projected improvements be strictly limited to the amount of $8500.

It was moved and carried that a sum of $850 be set apart annually in a separate fund, to meet the interest on the loan, and to provide a sinking fund for its retirement. Messrs. Hess, Plack, and Vogleson were appointed a Committee to secure the $8500 loan.

Upon motion of Mr. Swaab, Mr. Plack was appointed architect of the Club in charge of the projected improvements.

Adjourned Meeting, June 9, 1910.—Present: President Easby, Vice-President Christie, Directors Cochrane, Develin, Plack, Swaab, Hutchinson, Mebus, Worley, the Secretary, and the Treasurer.

The Treasurer presented a report showing the present financial condition of the Club, and, following this, it was ordered that the President and Treasurer be authorized to renew the existing loan of $1500 at the Colonial Trust Company for thirty days, and to borrow an additional $1000 for thirty days, if it appeared to them necessary.

The resignations of George H. Benzon, Jr., H. C. Felton, James C. Newlin, E. Collins, Jr., and J. Edward Whitfield were accepted as of even date.

The Committee on Improvements to the Club-house presented a report, stating that means had been found for raising the $8500 loan to be spent on improvements to the Club. On motion, F. K. Worley was added to the Committee appointed to secure this loan.

It was ordered that a Committee of three be appointed by the Chair to study the By-Laws and present to the Board definite recommendations for changes therein.

ABSTRACT OF MINUTES OF THE CLUB.

Business Meeting, April 2, 1910.—The meeting was called to order by President Easby at 8.35 p. m., with 104 members and visitors in attendance. The minutes of the regular meeting of March 19th were approved as printed in abstract. The President announced that at the last meeting of the Board Mr. S. M. Swaab had been elected Director to fill the vacancy caused by the resignation of Mr. George T. Gwilliam.

Following a report of the Tellers, the President declared the following elected to membership: Active, Carl F. Bierbauer, William F. Newberry, Morton M. Price; Associate, Hugh P. Fell, Albert Schade; Junior, Lyle L. Jenne, Alfred R. Powers, Wilson S. Yerger.

Mr. Frank B. Gilbreth, visitor, presented the paper of the evening, entitled "The Economic Value of Motion Study in the Trades," which was discussed by Messrs. Harrison Souder, John C. Trautwine, Jr., Charles M. Mills, H. M. Chance, Carl G. Barth and others.

Regular Meeting, April 16, 1910.—The meeting was called to order by President Easby at 8.35 p. m., with 104 members and visitors in attendance. The minutes of the Business Meeting of April 2d were approved as printed in abstract.

Dr. Henry Leffmann presented the paper of the evening, entitled "The Development of Correct Notions as to the Form and Position of the Earth," which was discussed by Messrs. James Christie, Carl Hering, John C. Trautwine, Jr., S. M. Swaab, John C. Parker, H. M. Chance and others.

Special Meeting, April 30, 1910.—The meeting was called to order by President Easby at 8.35 p. m., with 83 members and visitors in attendance.

Mr. Martin Nixon-Miller, Active Member, presented the paper of the evening, entitled "A Trip Across Panama: Life and Conditions in the Canal Zone," which was illustrated by about 200 lantern slides taken by the official government photographer of the Canal Zone. An informal discussion by a number of the members followed the paper.

Business Meeting, May 7, 1910.—The meeting was called to order by President Easby at 8.35 p. m., with 74 members and visitors in attendance. The minutes of the Regular Meeting of April 16th were approved as printed in abstract.

The President announced the death of Mr. John H. Converse, Active Member. Mr. Converse was elected May 17, 1884, and died May 3, 1910. Upon motion of Mr. Plack, it was ordered that a Committee be appointed to prepare a memorial.

Following a report of the Tellers, the President declared the following elected to membership: Associate, William G. Bickell, Herbert M. Fetter, and Nathan Shute; Junior, William P. E. Hitner, Alan B. Mills, and Walter B. Murphy.

Mr. John Reid, visitor, presented the paper of the evening, entitled "The Fruhling Suction Dredge," which was discussed by Messrs. William Easby, Jr., Robert Schmitz, E. H. Rigg, A. M. Loudenslager, H. C. Berry, and Mr. Reid.

Regular Meeting, May 21, 1910.—The meeting was called to order by President Easby at 8.35 P. M., with 68 members and visitors in attendance. The minutes of the special meeting held April 30th and of the business meeting held May 7th were approved as printed in abstract.

Mr. Grafton Greenough presented a memorial to Mr. John H. Converse, which had been prepared by Mr. Greenough and Mr. James Christie.

Mr. Carl P. Nachod, Active Member, presented the paper of the evening, entitled "An Automatic Signal for Electric Railways," which was discussed by Messrs. E. J. Dauner, Richard Gilpin, William Easby, Jr., John C. Trautwine, 3d, Harold Goodwin, Jr., and others.

Business Meeting, June 4, 1910.—The meeting was called to order by the President at 8.40 P. M., with 90 members and visitors in attendance. The minutes of the regular meeting of May 21st were approved as printed in abstract.

The President announced the death of Mr. Eugene D. Hays, Active Member of the Club since December 19, 1903.

It was announced that the Board of Directors had elected the following to serve as the Committee on Nominations:

Henry H. Quimby, *Chairman*,
Thomas C. McBride,
William C. Kerr,
Henry Leffmann,
W. B. Riegner,
John C. Parker,
E. M. Evans.

Following a report of the Tellers, the President declared the following elected to membership: Active, Robert Coe, Wm. H. Evans, Ernest H. Greenwood, Laurence G. Hanmer, Robert B. Owens; Associate, George E. Dale, Kennedy Duff, George C. Fry, Oswald M. Milligan; Junior, Jerome W. Howe, Edmund G. King, John A. Robb.

Mr. J. Vipond Davies, visitor, presented the paper of the evening, entitled "The Construction of a Rapid Transit Railroad in Relation to the Handling of Passengers," which was discussed by Messrs. C. M. Mills, J. C. Parker, S. M. Swaab, and others. Upon motion of Mr. Mills, a vote of thanks was extended to Mr. Davies for his interesting paper.

THE ENGINEERS' CLUB OF PHILADELPHIA

1317 Spruce Street

OFFICERS FOR 1910

President

WM. EASBY, JR.

Vice-Presidents

Term Expires 1911
JAMES CHRISTIE

Term Expires 1912
HENRY HESS

Term Expires 1913
CHARLES HEWITT

Secretary
W. P. TAYLOR

Treasurer
J. A. VOGLESON

Directors

Term Expires 1911	*Term Expires 1912*	*Term Expires 1913*
H. P. COCHRANE	EDW'D S. HUTCHINSON	DAVID HALSTEAD
R. G. DEVELIN	CHARLES F. MEBUS	E. J. KERRICK
H. E. EHLERS	S. M. SWAAB	PERCY H. WILSON
W. L. PLACK	A. C. WOOD	F. K. WORLEY

STANDING COMMITTEES OF BOARD OF DIRECTORS

House—W. L. Plack, H. P. Cochrane, P. H. Wilson, A. C. Wood, F. K. Worley.
Meetings—W. P. Taylor, Chas. Hewitt, A. C. Wood, S. M. Swaab.
Membership—Chas. Hewitt, James Christie, Chas. F. Mebus.
Finance—James Christie, H. E. Ehlers, Henry Hess.
Publication—Chas. F. Mebus, R. G. Develin, J. A. Vogleson.
Library—H. P. Cochrane, Edward S. Hutchinson, H. E. Ehlers.
Publicity—David Halstead, S. M. Swaab, W. P. Taylor.
Advertising—H. E. Ehlers, E. J. Kerrick, R. G. Develin.

MEETINGS

Annual Meeting—1st Saturday of February, at 8.15 P. M.

Stated Meetings—1st and 3d Saturdays of each month, at 8.15 P. M., except between the fourteenth days of June and September.

Business Meetings—When required by the By-Laws, when ordered by the President or Board of Directors, or on the written request of twenty-five Voting Members of the Club.

The Board of Directors meets on or before the 3d Saturday of each month, except June, July and August.

ISSUED IN

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PROCEEDINGS

OF

THE ENGINEERS' CLUB

OF

PHILADELPHIA

Edited by the Publication Committee

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Vol. XXVII. OCTOBER, 1910. No. 4

PAPER NO. 1089.

SUBMARINES.

SIMON LAKE.
(Visitor.)

Read March 19, 1910.

WHEN the United States Government in 1893 advertised for inventors to submit designs for the construction of a submarine torpedo boat, it is doubtful if a "corporal's guard" of officers in the United States service could have been found that had any faith in this type of vessel.

The submarine boat at that time was considered as great a curiosity by the majority of people as the flying machine was previous to the public flights of the Wright brothers a little more than a year ago. At that time neither the United States, England, Russia, nor any of the European countries were in possession of what might be termed a practical submarine vessel.

The French Government had one experimental vessel in commission, called the "Gymnote," and another under construction, which was called the "Gustave Zede." The latter was launched in June, 1903. Both these vessels were of the diving type, and operated on the same principle as numerous others that had been experimented with during the nineteenth century.

The records show that nearly a hundred submarine boats have

been projected or built to operate on practically the same principle as the "Gymnote," most of them vessels of small size. Drzwiecki, the inventor of the torpedo-firing apparatus which bears his name, built a large number of small vessels of this type for the Russian Government in the seventies. They were one-man boats.

Several boats were built by the Confederates during the Civil War which operated on the same principle. The attempts to use these vessels, however, usually resulted disastrously, the boats having a tendency to dive head-first to the bottom, in some cases remaining there permanently, especially if the bottom was soft. If the bottom was hard and the hull was sufficiently strong to withstand the shock, the vessel would rebound to the surface.

Hovgaard, in his book on submarine navigation, refers to one of the early French boats of the diving type called "Le Plongeur." This boat was the most ambitious attempt to construct a submarine vessel during the nineteenth century. She was about 140 feet long, 20 feet broad, and 10 feet deep. Her beam was, therefore, twice her depth. She had an oval form in cross-section and was presumably braced to resist the pressure of water when submerged. This form of hull would need to have been strongly braced to resist collapse at any considerable depth, as her plate was said to be only ½ inch near the keel and ⅜ inch throughout the rest of the vessel. She was propelled by a compressed-air engine which developed 80 HP when working with air at twelve atmospheres. It is stated that the engine always worked well. Her displacement was about 200 tons. In his description of this vessel Hovgaard says:

"The greatest difficulty was the regulation of the motion in a vertical sense. Operations commenced by closing all openings, and then water was let into the two air reservoirs, and into the watertight compartments, until only the top of the conning tower was above the surface. It was found to be pretty easy to go like this, awash, along the surface of the sea. It was expected that the depth of immersion could be determined by small changes in displacement, namely, by using the piston in the regulating cylinder, but the experiment showed this to be quite impossible, and the vessel would often touch the bottom, even in 30 feet depths, before the motion could be changed. When striking tolerably hard bottom, such as sand, the vessel would rebound like an india-rubber ball. Thus the 'Le Plongeur' would advance, striking alternately the bottom and remounting to the surface.

"The horizontal rudders and the regulating cylinders acted much too slowly. Most frequently they had to resort to the donkey pump or to air-pressure to expel water, but then the ascension would take place very violently, and when at the surface, the vessel would be found to have a buoyancy of several cubic meters. A vertical screw was therefore fitted to regulate the motion up and down; it was worked by hand. In this way the equilibrium under water was kept, but only for a very short time."

The result of the experiment was that it was possible to make a submarine boat slide along the bottom in the way described above, and also to move steadily awash.

It will be seen from the above description, and the abandonment of the vessel, that this boat, like many others of the type, was unmanageable when attempts were made to run her in a submerged condition. With her shallow depth and great beam it is probable that the failure of this vessel was largely due to a lack of longitudinal stability, which stability, in the speaker's estimation, is the first and most important thing in the designing of a submarine vessel.

The Confederates attempted to use the submarine boat during the Civil War and succeeded in sinking one of the United States warships. They called the little submarine boats which they constructed at that time "Davids," and the name was a most apt one. The next war will probably prove that the submarine "Davids" will be able, like David of biblical fame, to destroy the great "Dreadnaughts," or Goliaths, of the present day.

Previous to the beginning of the nineteenth century some experiments had been made in the construction of submarine vessels. The first important one of which there is any record was constructed in the seventeenth century by Cornelius Debrell, a Dutchman, who lived in England during the reign of James I. Nearly a hundred years later a man by the name of Day built a submarine and made a wager that he could descend to a depth of 100 yards and remain there twenty-four hours. He did, and according to latest advices, is still there.

The most authentic information at hand, however, regarding the early submarines, is of a boat built by a Connecticut man, Dr. David Bushnell, who lived in Saybrook during the Revolutionary War. He built a small submarine vessel called the "American Turtle," with which he expected to destroy the British fleet anchored off New

York during its occupation by General Washington and the Continental Army.

"Thatcher's Military Journal" gives an account of an attempt to sink a British frigate, the "Eagle," of 64 guns, by attaching a torpedo to the bottom of the ship by means of a screw manipulated from the interior of this submarine boat. A sergeant who operated the "Turtle" succeeded in getting under the British vessel, but the screw which was to hold the torpedo in place came in contact with an iron strap, refused to enter, and the implement of destruction floated down stream, where its clockwork mechanism finally caused it to explode, throwing a column of water high in the air and creating consternation among the shipping in the harbor. Skippers were so badly frightened that they slipped their cables and went down to Sandy Hook. General Washington complimented Dr. Bushnell on having so nearly accomplished the destruction of the frigate.

If the performance of Bushnell's "Turtle" was such as described, it seems strange that our new government did not immediately take up his ideas and make an appropriation for further experiments in the same line. When the attack was made on the "Eagle," Dr. Bushnell's brother, who was to have manned the craft, was sick, and a sergeant who undertook the task was not sufficiently acquainted with the operation to succeed in attaching the torpedo to the bottom of the frigate. Had he succeeded, the "Eagle" would undoubtedly have been destroyed, and the event would have added the name of another hero to history and might have changed the entire method of naval warfare. Instead of Bushnell being encouraged in his plans, however, they were bitterly opposed by the naval authorities. His treatment was such as finally to compel him to leave the country, but he returned after some years of wandering, and under an assumed name, settled in Georgia, where he spent his remaining days practising his profession.

Robert Fulton, the man whose genius made steam navigation a success, was the next to turn his attention to submarine boats, and submarine warfare by submerged mines. A large part of his life was devoted to the solution of his problem. He went to France with his project and interested Napoleon Bonaparte, who became his patron and who was the means of securing sufficient funds to build a boat which was called the "Nautilus." With this vessel Fulton made numerous descents, and it is reported that he covered 500 yards in a submerged run of seven minutes.

In the spring of 1801 he took the "Nautilus" to Brest, and experimented with her for some time. He and three companions descended in the harbor to a depth of 25 feet and remained one hour, but he found the hull would not stand the pressure of a greater depth. They were in total darkness during the whole time, but afterward he fitted his craft with a glass window 1½ inches in diameter, through which he could see to count the minutes on his watch. He also discovered during his trials that the mariner's compass pointed equally as true under water as above it. His experiments led him to believe that he could build a submarine vessel with which he could swim under the surface, and destroy any man-of-war afloat. When he came before the French Admiralty, however, he was met with blunt refusal, one bluff old French admiral saying: "Thank God, France still fights her battles on the surface, not beneath it," a sentiment which apparently has changed since those days, as France now has a large fleet of submarines. After several years of unsuccessful efforts in France to get his plans adopted, Fulton finally went over to England and interested William Pitt, then chancellor, in his schemes. He built a boat there, and succeeded in attaching a torpedo beneath a condemned brig provided for the purpose, blowing her up in the presence of an immense throng. Pitt induced Fulton to sell his boat to the English Government and not bring it to the attention of any other nation, thus recognizing the fact that if this type of vessel should be made entirely successful, England would lose her supremacy as the "Mistress of the Seas."

Fulton consented to do so, but would not pledge himself regarding his own country, stating that if his country should become engaged in war, no pledge could be given that would prevent him from offering his services in any way which would be for its benefit.

The English Government paid him $75,000 for this concession. Fulton then returned to New York and built the "Clermont" and other steamboats, but did not entirely give up his ideas of submarine navigation, and at the time of his death was at work on plans for a much larger boat.

Fulton had a true conception of the result of submarine warfare, and in a letter he says: "Gunpowder has within the last three hundred years totally changed the art of war, and all my reflections have led me to believe that this application of it will, in a few years, put a stop to maritime wars, give that liberty on the seas which has been long and anxiously desired by every good man, and secure to

Americans that liberty of commerce, tranquillity, and independence which will enable citizens to apply their mental and corporeal faculties to useful and humane pursuits, to the improvement of our country and the happiness of the whole people."

After Fulton's death spasmodic attempts were made by various inventors looking to the solving of the difficult problem, but no very serious efforts were put forth until the period of the Civil War, and then a number of submarine boats were built by the Confederates. These boats, as already referred to, were commonly called "Davids," and it was one of them that sank the United States steamship "Housatonic" in Charleston Harbor on the night of the 17th of February, 1864. This submarine vessel drowned four different crews, a total of thirty men, during her brief career. At the time she sank the "Housatonic" her attack was anticipated, and sharp lookout was kept at all times; but notwithstanding their vigilance she succeeded in getting sufficiently close to plant a torpedo on the end of a spar, and sink this fine, new ship of 1400 tons displacement.

According to one of the officers of the "Housatonic," the attack was made in the following manner: "About 8.45 P. M. the officer of the deck, Acting Master M. K. Crosby, discovered something in the water about a hundred yards away coming directly toward the ship; the time from its appearance until it was close alongside being about two minutes, during which time the chain was slipped, engine backed, and all hands called to quarters. The torpedo struck the ship forward of the mizzen mast on the starboard side, in line with the magazine, and as we had the after pivot gun pivoted to port, we were unable to bring a shot to bear upon her. About one minute later she was close alongside and the explosion took place, the ship sinking stern first, and heeling to port as she sank. Most of the crew saved themselves by going into the rigging while a boat was despatched to the 'Canandaigua.' The vessel came gallantly to our assistance and succeeded in rescuing all but a few of the officers. What became of the 'submarine boat' was a mystery not solved until a few years ago, when some divers in searching about the wreck of the sunken steamship found, a few feet away from her, the 'David' with skeletons of her crew still aboard. It was found that the hatch was open, and it is supposed that the water thrown up by the torpedo caused her to founder with all hands."

It will be observed by the above description of the attack that the boat was not in a submerged condition at that time, but that her

buoyancy was so reduced as to present a very small target. This enabled them to manœuver the boat sufficiently near the "Housatonic" to prevent discovery until too late to ward off the attack.

The author was fortunate enough several years ago to receive a visit from Mr. Charles H. Hasker, of Richmond, Va., formerly Lieutenant of the Confederate ironclad "Chicora," stationed in Charleston Harbor. While experiments were being made with the submarine vessel just described, Mr. Hasker volunteered as one of the crew for the experimental trip about the river, and was one of four that escaped when the vessel went down. He gave me the following account of her sinking:

"The submarine had a line fast to the steamer 'Etawan,' off Fort Johnson; the crew were all in their places, and had started the craft ahead. The buoyancy of the vessel had been reduced so that only the hatch combings were above the water. The side submerging vanes were operated by a tiller connected with the athwartship shaft, and were held in a horizontal position by means of a stick of wood placed beneath. When the vessel started ahead, Lieutenant Paine attempted to cast off the line which was made fast around the hatch combing. He became entangled in the line, causing the boat to sheer slightly and careening her sufficiently to permit the water to come in the forward hatch. The Lieutenant, in his struggles to extricate himself, struck the prop which supported the ends of the tiller, thus causing it to drop to the floor and forcing the forward ends of the vane downward. This, of course, immediately pulled the bow of the boat under water." Mr. Hasker occupied the forward seat just at the hatchway. Lieutenant Paine succeeded in getting out as soon as he saw the boat was going to sink, and Mr. Hasker grasped the edges of the hatch combing and finally forced his way through the column of inrushing water, which was, by this time, coming in with great force. But before he was entirely out of the opening the pressure of the water closed the hatch door, which caught his left leg below the knee. The pressure of the water was so great against the door that it crushed the muscles of the leg, and held him in this position until the vessel had reached the bottom in seven fathoms of water. The hull then being filled with water, equalized the pressure so that he was able to lift the door, and being an expert swimmer, he swam to the surface. The boat went down head-first, and before the after hatch got under water, two other men succeeded in escaping, the other five being drowned.

Notwithstanding that this was the third time the boat was sunk she was again raised and a new crew was found to man her. Mr. Hasker states that he was unfortunate enough to be captured at the evacuation of Morris Island, about one week after this occurrence, was kept prisoner for fourteen months, and was at Hilton Head prison when he heard that the submarine had finally accomplished her mission in sinking the U. S. S. "Housatonic."

This brings us to 1893, and to the more recent attempts to solve the problem of submarine navigation, which at the present day is an accomplished fact, and every nation of importance is adding submarine torpedo boats to its fleet for purposes of defense, and many of them are even now proposing vessels for offensive as well as defensive purposes.

In 1877 Mr. John P. Holland built a small boat which was called the "Fenian Ram." It is stated that this vessel was built by capital furnished by the "Clan-na-Gaël," with the idea of using it against the British fleet in an attempt to free Ireland. It is reported that Mr. Holland, who was a school-teacher, had been exiled from that country because of his political activity. From the published description of this boat it would appear to be very similar to the small boat turned out by Drzwiecki for the Russian Government, in that it operated with a vertical and horizontal rudder in the same manner as other boats of the diving type which have been mentioned.

Previous to the appropriation made in 1893, Mr. Holland had built several small boats of this type, and it is reported that he met with considerable success in navigating them.

Mr. Baker, of Chicago, had built a vessel of quite a different type. His boat was elliptical in shape and in form resembled the "Goubet" type of vessel. It was propelled by screws located about midship on either side of the vessel. These screws were operated by gear wheels in such a manner that the angle of thrust could be changed to submerge the boat; the vessel having a certain reserve of buoyancy, the propellers could be set at such an angle as to cause the vessel to submerge until she reached a given depth, and then, by slightly reducing the angle, the vessel would move forward theoretically on a straight course and on a line which would be a mean between the upward pull due to the buoyancy of the vessel and the downward and forward pull due to the inclination of the propellers.

It is reported that this vessel made a number of successful trials in the waters of Lake Michigan. The form adopted by Baker was

one well adapted for giving great stability, but was not suited to speed. It was largely due to Baker's success, however, and to the report made by a board of officers which watched the performances of this craft in 1892 that the first appropriation of $200,000 was made for the construction of the United States submarine. When the appropriation was made, Baker was so sure of receiving the award for the contract that he moved from Chicago to Washington with the idea of being close to the Government authorities while developing the plans for his large vessel. He died shortly after moving there. Mr. Holland, Mr. Baker, and the author, it is believed, were the only inventors of submarine craft that were present with plans in Washington at the opening of bids in June, 1893. The author did not submit a proposition to build a vessel, as the advertisement stated that the department would consider designs even if they were not accompanied by tenders for construction; and if the designs were considered meritorious, the department would itself arrange for the construction of the vessel. The author's designs were submitted to a board to pass upon their merits, and he was later advised by the late Admiral Matthews that his designs were looked upon with considerable favor by some of the members of the board at that time, but as the Holland designs were accompanied by a bid to construct, with a bond for performance, and backed by a company, the Navy Department wa s reluctant to take upon itself the responsibility of the development of a vessel from designs only. The matter of awarding a contract was held in abeyance for over a year, and finally the award was made to the Holland Company for the construction of the "Plunger" on certain guarantees of performance, which guarantees were destined never to be fulfilled under the first contract, as this boat, the "Plunger," was to have done many things that even to this day have never been accomplished by any submarine boat. She was to have a speed of about 16 knots and be able to go from light condition to that of complete submergence in twenty seconds. Her construction extended over a period of several years, and she was finally abandoned in 1900, after the Holland Company had received additional appropriations and brought out a much simpler vessel in the "Holland," the first United States submarine torpedo boat which went into commission.

The following cuts show some of the earlier submarines, as well as the more recent and successful boats now in the possession of the most important navies.

Fig. 1 is the first Lake design of a submarine boat previously referred to, and was submitted to the United States Government in 1893, in response to a public advertisement asking inventors to submit bids for submarine boats for the United States Government.

Particular attention is called to some of the features of this design. Two hydroplanes will be noticed on either side at the bow and the stern, with fore-and-aft rudders for correcting trim. The wheels for navigating on the bottom are indicated. This boat was fitted with four torpedo tubes, two forward and two aft. This view is made from a tracing of the plans submitted to the United States Navy Department in 1893.

Fig. 2 is a sectional view of the "Holland." This is the first

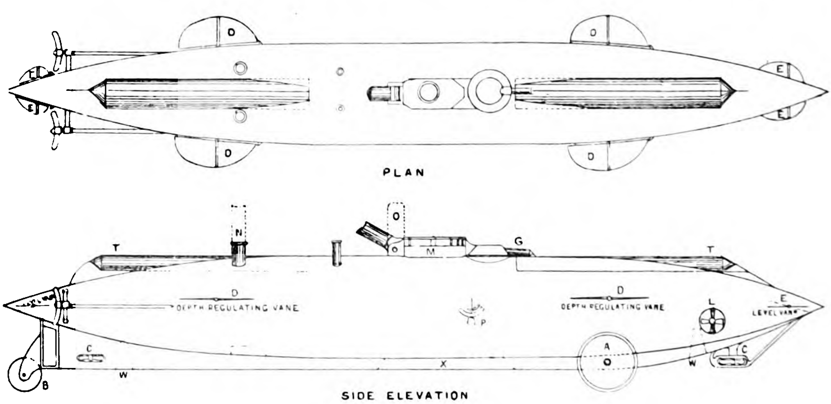


FIG. 1.

United States submarine boat, and is the boat previously referred to, which took the place of the "Plunger," the first United States boat contracted for. This type of boat operates in the same manner as the early French and Spanish boats. It also operates on the same principle as the Whitehead torpedo, except that the intelligent control of man operates the vertical and horizontal rudders rather than automatic appliances. The principle of operation, however, is the same.

These boats are still built in the cigar-shaped form, which is, without doubt, the best form for under-water speed, but has certain disadvantages as a surface sea-going craft, and is more difficult to control when operating submerged. The earlier boats of the Holland type were lacking in stability and were very erratic as to their performance,

having a tendency, as did the early boats of the same type constructed in France and Spain, and as did the boats of similar type before referred to that were constructed during the Civil War, either to run their nose into the bottom or to broach to the surface.

These vessels have been much improved, however, in the last three or four years, owing to the greater experience in their design and construction, and the necessity now—since competition has been permitted in the securing of submarine vessels for the United States

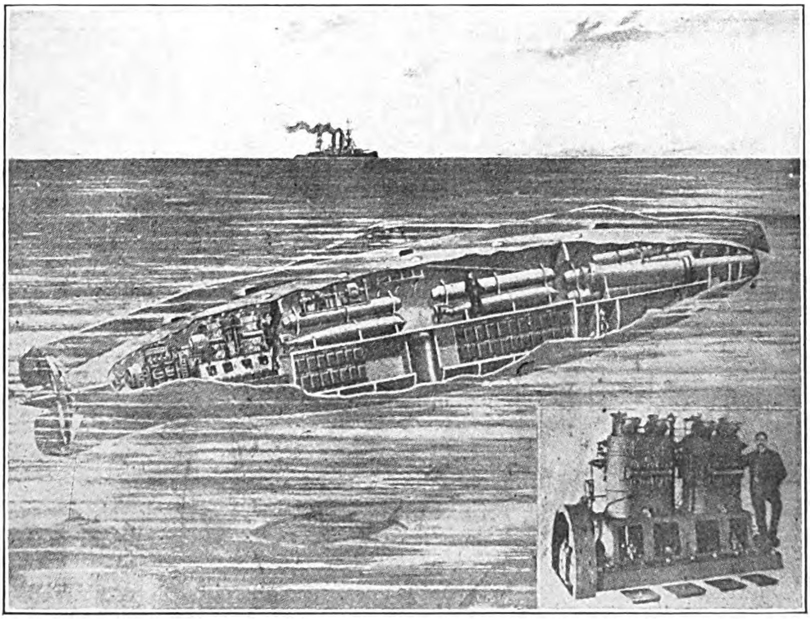


FIG. 2.

navy—of providing vessels that will meet the requirements of the United States naval authorities. The standard of performance now required by the United States navy is the most severe of any country.

Fig. 3 is a sectional elevation and plan of the "Protector." Early in 1901 the author received a request to come to Washington and submit designs to the navy department for the construction of submarine torpedo boats of the Lake type, as the department was not satisfied with the performance of its Holland type of submarine then. The designs of the "Protector" and of the cruiser type of

boat were submitted to the Board on Naval Construction, at that time composed of five admirals, and the author was informed that his designs were considered superior to anything yet proposed in the way of submarine boats, either in this country or abroad. Congress had always specified Holland boats, notwithstanding the protest of many officers in the navy department. It was suggested, however, that if a submarine boat were constructed with private resources, it was within the power of the navy department to see that such a vessel would be given a fair trial when completed, and that the

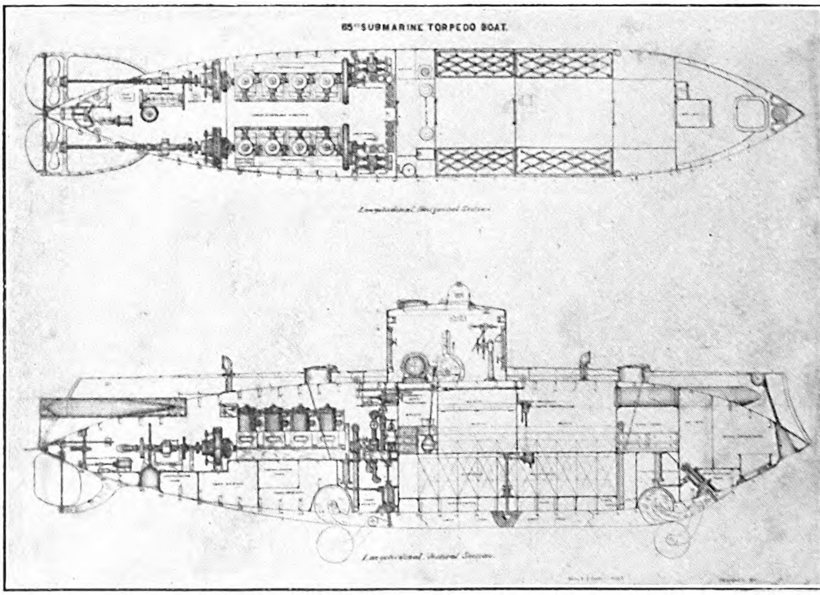


Fig. 3.

department could make such recommendations as were impossible for Congress to ignore. On the strength of these promises the author started to construct the "Protector." In this view the diving compartment is shown.

Fig. 4 shows one of the later German Krupp boats cruising on the surface. These boats are fitted with the buoyant superstructure and hydroplanes. The latest boats are fitted with omniscopes.

One of the features of the Lake type of boat has been that it carries its fuel outside of the living quarters of the crew, in especially de-

signed tanks in the superstructure, which tanks are galvanized to prevent the escape of dangerous fluids or gases. Both the German boats and the Italian boats have adopted this feature, the only difference being that the fuel tanks were built up directly over the hull of the vessel rather than being built circular in form and galvanized after construction. It appears that the fuel leaked through this built-up tank in the Italian boat, "Foca," down into the hull, where it became ignited and caused an explosion which blew up the

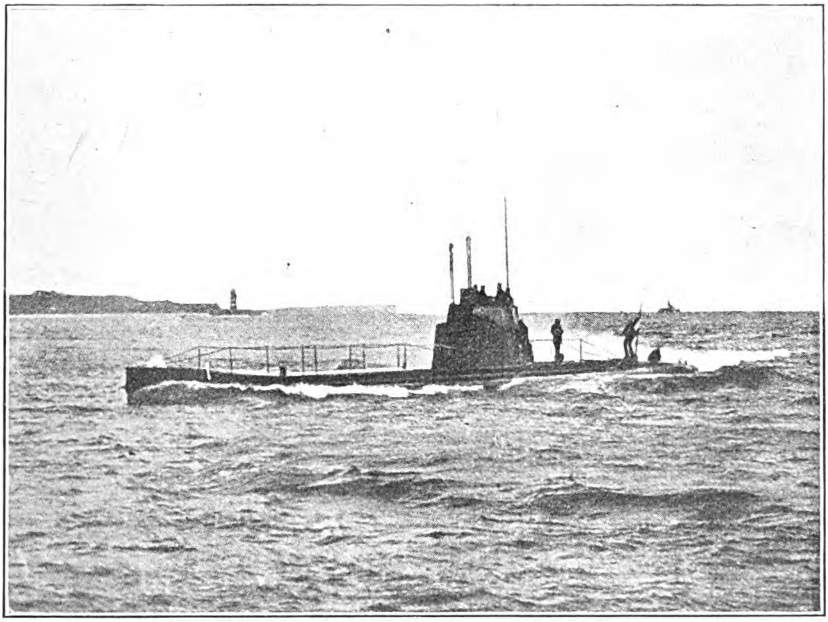


FIG. 4.

vessel and killed her crew of twenty-three men. This was probably due to some careless workmanship or neglect on the part of some members of the crew to take proper precautions in seeing that the pipe connections where they came through the hull were properly made. It is impossible to provide against the ignorance and carelessness of workmen and members of the crew. Many explosions have occurred, both in this country and abroad, on submarine boats, and numerous lives have been sacrificed which, with a little more thought and care, might have been saved.

There are a number of dangerous things in connection with submarine boats. The gas which is given off in large quantities from the batteries is hydrogen, and is very explosive. If the fumes of the gas are not pumped out as rapidly as they are given off, an explosion is very likely to occur. The fumes of gasoline when mixed with the proper proportion of air are also highly explosive. For this reason Lake boats always carry fuel outside of the main hull, and, fortunately, so far no lives have been lost on any of these boats, although a number of men were nearly lost last August on the Russian sub-

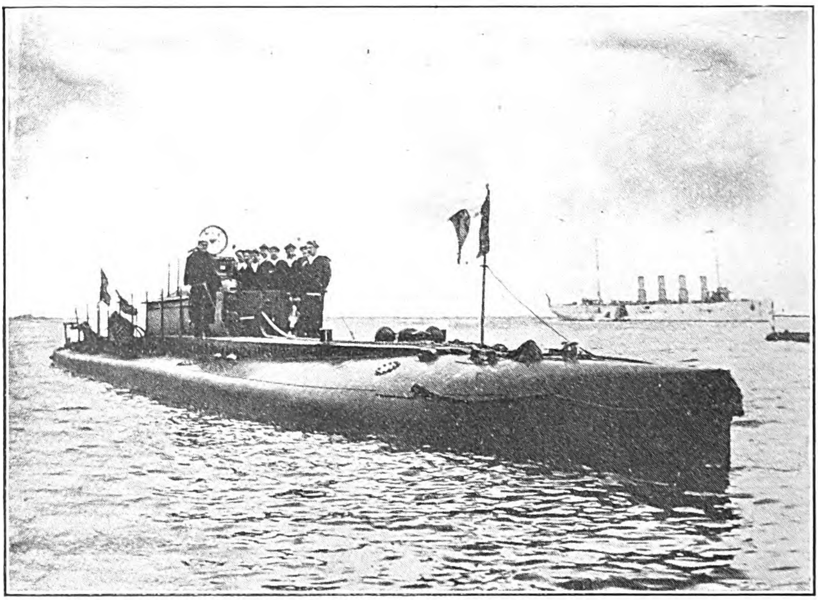


Fig. 5.

marine "Dragon." This was before the boat was entirely completed, and was caused by the carelessness of one of the workmen in pouring several gallons of gasoline into the hull through an open pipe before the same was connected up. The accident resulted in severe injuries to a number of the men and about $100,000 damage to the boat.

The dangers of gasoline have brought about extensive experiments in trying to develop heavy oil engines for submarine boat service. Hundreds of thousands of dollars have been expended in trying to

produce a satisfactory engine of this class. All governments are now calling for heavy oil engines, and if experiments now well advanced prove their practicability, it will bring about a revolution in the construction of internal combustion engines, not only for submarines, but for all other classes of boats using liquid fuel.

Fig. 5 shows one of the latest French submarines. This boat shows the addition of the buoyant superstructure and is also fitted with hydroplanes.

Fig. 6 shows two of the Lake boats, 161 feet long, under construction for the United States Government at Newport News. The one with the hull nearly completed is the "Seal"; the other is the "Tuna." The "Seal" is the largest and most powerful submarine boat now under construction for the United States Government.

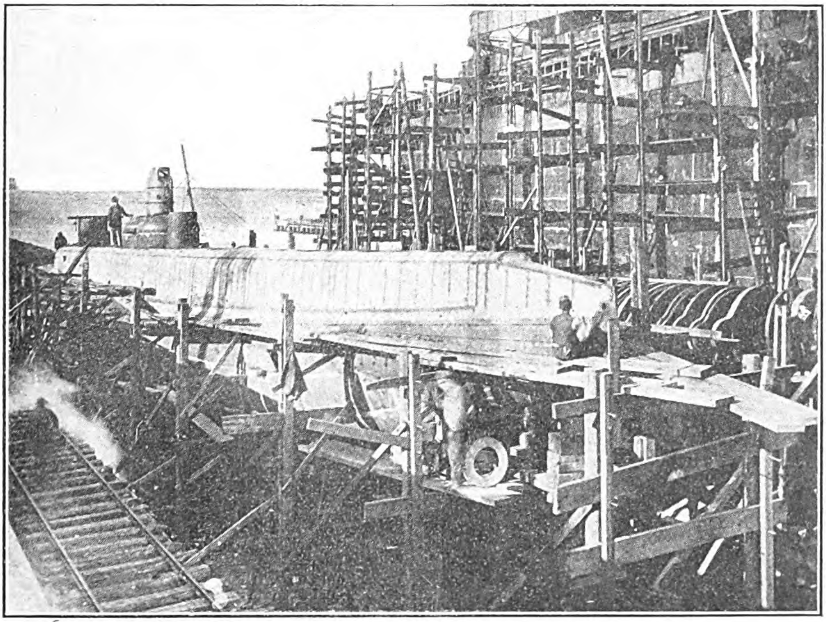


FIG. 6.

The author is free to admit that there are certain mysteries connected with the control of submarine vessels in a vertical plane that are not easily explained. While the problem of perfect control of such vessels in a vertical plane by the use of hydroplanes was solved

model was pulled. The tank was so constructed that the water could be driven by the model at a constant velocity by the use of propellers; the velocity of the stream could be increased or diminished as desired.

This view shows a model of the "Protector" submerged, being tried out in this tank. The wave line at the surface is plainly shown. The stream lines are also plainly shown by the use of black threads, many of which were secured to a rod by one end, the other end being free. The rod could be moved to any desired position and the stream lines observed as they passed over, under, or to either side of the model.

The model was free to move up or down, a transverse shaft running through the model at a point half-way between the centers of buoyancy and gravity; wheels were fixed to the outer ends of this shaft. These wheels ran up and down on vertical wires on either side of the model.

On the reserve buoyancy being reduced in the model to about that used in the full-size boat, the hydroplanes would cause the boat to submerge or emerge on a level keel, in the same manner as the full-sized ship. It was found that with a certain inclination of hydroplane the vessel would submerge to a certain depth and automatically maintain that depth as long as the velocity of the stream was fairly uniform. To go deeper required a greater angle of hydroplane or horizontal rudder. Just why a vessel will submerge only to a given depth with a certain angle of hydroplane is not altogether clear. At the time these tank experiments were made this fact did not impress itself on the author's mind as much as it has since, due to some recent trials with one of our foreign boats, which was submerged with a reserve buoyancy of about 600 pounds. When first submerged, it was running with an inclination down by the bow of about 1 degree. The boat ran for thirty minutes, maintaining a constant depth of between 31 and 32 feet, without touching either the horizontal rudder or the hydroplanes. It was then noticed that the boat had changed her trim for 1 degree down by the bow to 1 degree down by the stern, which was gradually increasing. Still the boat maintained her uniform depth. A movement of 1 degree of the horizontal rudder brought her to a level keel. When she showed a tendency to submerge further, 2 degrees less inclination to the hydroplanes brought her back to her original depth with head of periscope about 1 foot above the surface, and she ran thirty minutes more without touching

anything, at which time she had again taken on an inclination of about 1½ degrees down by the stern. The boat was stopped, and it was found that she had lost all of her reserve buoyancy except about 10 pounds, and that a leaky valve had let about 600 pounds of water into the exhaust tank at the extreme after end of the boat. At rest she took an inclination of 5 degrees down by the stern.

Here was a condition that had never been previously noted in the author's experience, where the vessel ran at a uniform depth without touching anything, during which time she changed her reserve of buoyancy and changed her trim and yet maintained a constant depth.

This same phenomenon was later observed in another Lake boat, where, by moving men from one end of the boat to the other, the trim would be changed from down by the head to down by the stern, but the depth would remain constant, without changing inclination of either horizontal rudder or hydroplane.

With a certain reserve of buoyancy and a certain inclination of hydroplane, therefore, the vessel will always go to a corresponding depth and run constant at that depth until conditions are changed; indeed, the author has heard the commander of one of these boats state, for the information of the members of a trial board, after first noting the vessel's reserve of buoyancy: "I will now set the hydroplanes at 10 degrees down and the horizontal rudder 2 degrees up, and the boat will submerge to a depth of 30 feet and run constant at that depth"; which the vessel did without his touching anything after she started to submerge.

The testing tank also showed up another curious thing. A model of one of the early United States boats of the "Adder" type, with the cigar form of hull, and with quite a considerable surface buoyancy, would automatically dive by the head at about the angle shown in Fig. 8, when the bow would lightly touch the bottom of the tank, and then she would reverse her inclination and come to the surface at about the same angle at which she dived. At times she would reverse without touching the bottom. This model had a metacentric height corresponding to about 10 inches in a full-sized ship. It was very interesting to observe this porpoise-like motion, which kept up continuously, as long as the stream was flowing, and it was impossible to set the horizontal rudder in any position to overcome this tendency. The porpoising motion was so rapid that it was impossible to get any accurate observation of the stream lines, but it is believed that the explanation is much the same as of the hydroplane action, viz.,

as the vessel gathers headway, the water piles up over the cigar-shaped bow, which, combined with the increased frictional resistance due to the streams passing under the hull, causes the bow to submerge, and the vessel plunges toward the bottom. A cross-section parallel to the surface, through the hull near the bow as she is diving, would show (if she was moving forward at the same time) that there would be a tendency to create a vacuum under the forward portion of the vessel, which would tend to increase the inclination, and she would continue to dive until a sufficient inclination and depth was reached whereby the greater head of water at the bow reduced the

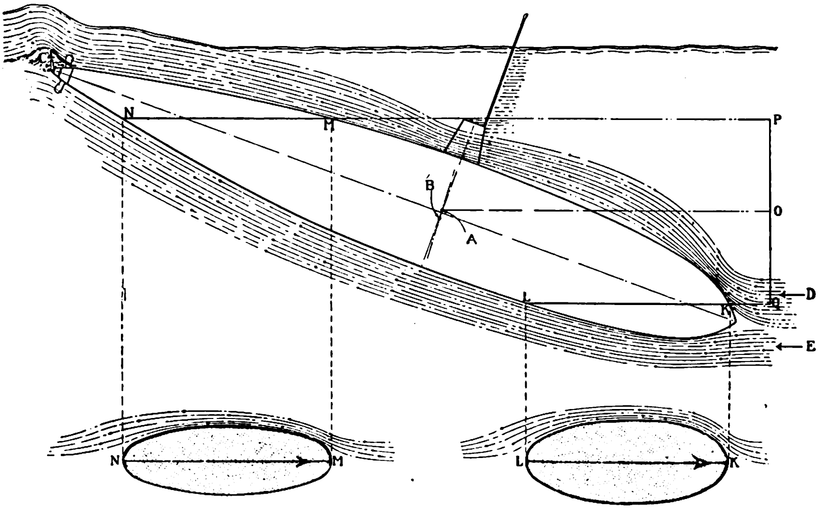


FIG. 8.

vacuum and consequent down pull on the bow, and at the same time the vacuum formed under the stern was proportionately increased, which, combined with the righting effect of the pendulum arm (her metacentric height) caused the forces to be reversed, and she would broach to the surface. The motion of the model would apparently synchronize, and the plunge toward the bottom and return to the surface again would occur with the regularity of clock-work. The obvious remedy for this tendency in a boat of the cigar-shaped form is to increase the metacentric height and the size of the control rudders and to keep in constant touch with the horizontal rudder.

The above theory may explain the fatal dives to the bottom of some of the vessels of the diving type.

Fig. 9 shows one of the advantages of the bottom wheels in surmounting obstructions. Running in waters not well charted, where it was assumed there were several fathoms of water, the keel struck and surmounted obstructions of unknown objects. The cushioning wheels take up the shock, and the vessel surmounts the obstruction without the hull coming in contact with the object.

Speed, as every engineer knows, is simply a question of lines and horse-power. The author has always felt that safety and ease of control should be the first consideration in the design of submarines. The submarine does not require great speed, especially under water.

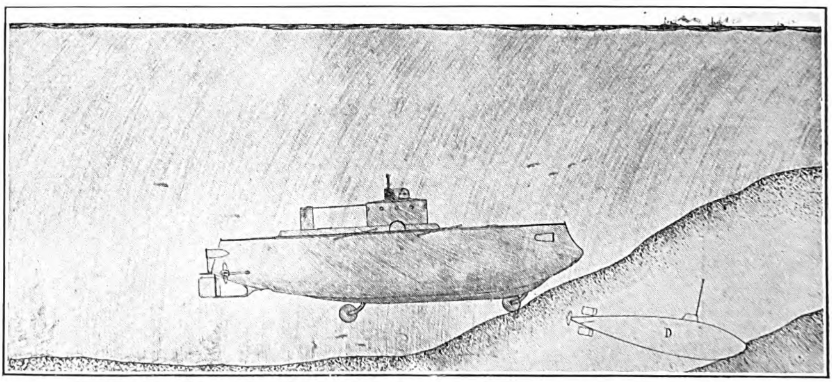


FIG. 9.

The submarine is the guerilla in warfare, and it is her province to lie in wait for her fleeter foe, the armored cruiser or battleship. For preventing a close blockade of a port a very slow submarine would have frequent opportunity to intercept a blockading squadron. Speed is now becoming more desirable, however, as the submarine is going to take the offensive in naval warfare rather than the purely defensive position to which these vessels have been considered adaptable.

Fig. 10 illustrates the author's opinion as to the proper method of making a submarine attack. The submarine is here shown running on a level keel, a sufficient distance below the surface so that when the omniscope and periscope are withdrawn there is absolutely nothing on the surface to betray the fact that a submarine is in the vicinity.

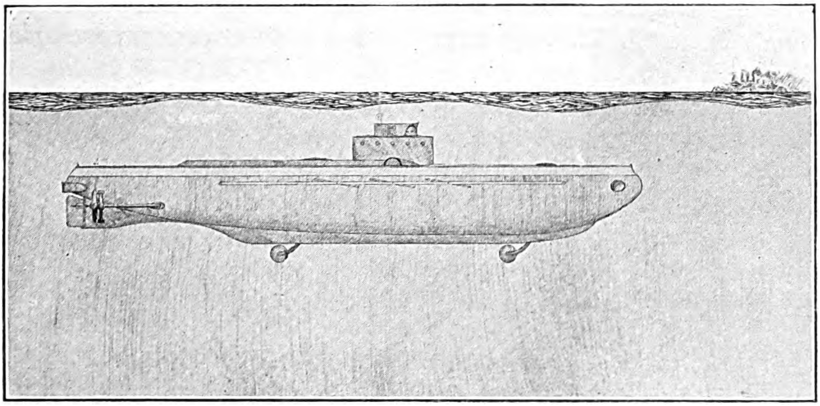


Fig. 10.

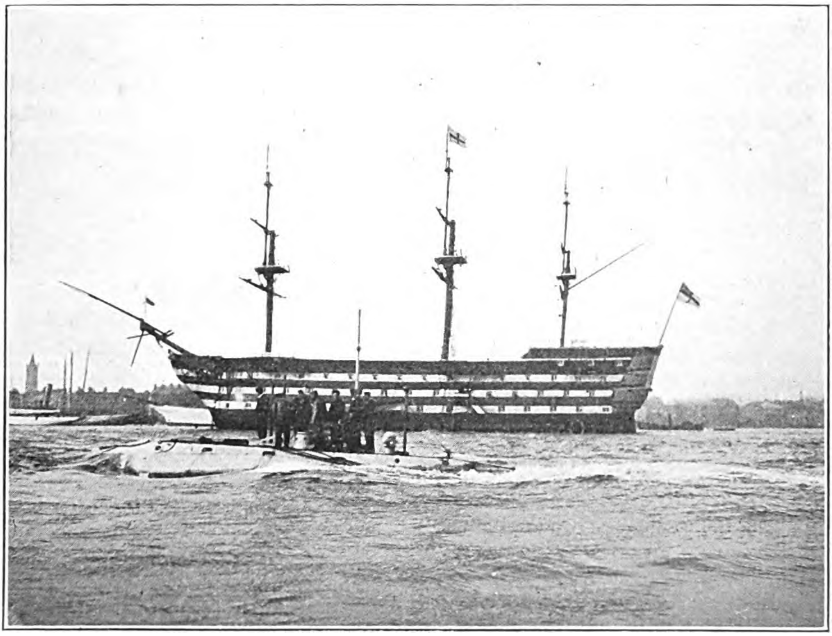


Fig. 11.

This represents the type of vessel which carries six of the deadly Whitehead torpedoes, all of which may be almost simultaneously fired: two at the bow, two at the stern, and two to either broadside. The periscope is kept housed except at the moment of taking an observation. Range-finding and direction-indicating devices are provided by means of which the navigator of the submarine may be constantly advised as to the position of the enemy. Observations may be made by suddenly shooting the head of the periscope just slightly above the surface and as rapidly withdrawing it. An observation may be taken and the distance of a known ship calculated in a space of time not exceeding two or three seconds, during which period no gun could be trained on so small an object as the head of a periscope, even if it was observed, which in a choppy sea is hardly likely, even at a distance of only 300 or 400 yards; and at a distance of a couple of thousand yards would be invisible even with a very powerful glass, provided the vessel did not have sufficient speed and the periscope did not remain above the surface long enough to create a wake. It is the wake of the periscope which attracts attention to a vessel running with the periscope above the surface all the time.

Fig. 11 shows one of the English submarines passing Nelson's old flagship, the "Victory." She is a relic of past days, and the little submarine passing in front of her a hundred years after the memorable battle of Trafalgar illustrates the most important advance made in the art of naval warfare in the history of the world.

DISCUSSION.

In reply to questions by members, Mr. Lake stated as follows:

All of the French boats, so far, have been built in France, and all of the recent French designs have been made by French officers. He thinks that Goubet, the designer of a little French boat shown, experimented privately. The United States Government has furnished no designs. Its latest call for tenders distinctly states that the Government has no designs.

Reference was made to what is known as the Board on Construction, which has been discontinued. There is now a General Board, of which Admiral Dewey is the head. The Board on Construction was composed of the heads of the Bureau of Construction, the Chief of the Ordinance Bureau, the Bureau of Engineering, the Bureau of Equipment, and the Chief Intelligence Officer. These men would get together and decide on all classes of ships, except submarines, which class was formerly decided upon only by Congress. The Naval Board formerly had nothing to do with this, due to the wording of the legislation. Now, however, it does, and the Department issues circulars to ship-builders and specifies what it wants in the way of armament and performance. Since the United

States has the advantage of getting competitive bids, the requirements are as severe as, if not more so than, those of any foreign government.

The difference between a horizontal rudder and a hydroplane is this: A horizontal rudder is placed at the bow of the boat or at the stern and has simply a guiding function, to direct the course of the vessel up or down. The hydroplanes pull the boat up or down bodily, as it were. In the "Lake" type of boat they have always been equally distributed, one an equal distance forward and another an equal distance aft of the center of gravity, so that the forces acting upon them tend to force the boat down bodily on a level keel, and they also lift the boat on a level keel. With a horizontal rudder, one must change the whole angle of the boat itself, while with the hydroplanes one instantly gets down pull or up pull.

Air is compressed in steel bottles. Under the present government requirements, all submarines must provide for a certain number of cubic feet of air up to as much as 2500 pounds per square inch. The United States Government made a number of trials in 1907 in which the "Fulton" and the "Lake" both remained submerged for a period of twenty-four hours. Mr. Lake had previously made experiments in 1897 to determine how long a crew could remain submerged living on air in the boat alone without drawing in an outside supply. The "Argonaut" was only 36 feet long, and was for a period of five hours submerged without drawing on any air-supply from outside. Eight men at Newport in the "Lake" remained for twenty hours under water without drawing on outside air, at the expiration of which time the air was getting a little thick, and Mr. Lake noticed that some of the men were losing interest in things about them. He had been observing the condition of the air by watching a lighted candle, measuring the height of the flame of the candle both at the top and at the bottom of the boat. In this way he could judge if carbonic acid gas was forming. He would repeat this test every hour, and after they had been submerged fifteen or sixteen hours he noticed that the flame began to diminish, which was the first indication of bad air. At the end of twenty hours it was impossible to keep the candle lighted. About that time the men began to get sleepy and to breathe rather heavily; some fresh air was then admitted from the storage bottles. The pumps were started and pumped the foul air out from the bottom of the compartment and the fresh air was admitted at the top; the candle flame then immediately brightened. They then remained for two hours longer, until the candle flame began to show signs of getting weak again, when they repeated the pumping operation and remained for another two hours, and so on. When they came to the surface, they immediately got under way and went back to Newport, and none of the men suffered any bad effects.

Boats have electric heaters and cooking is done with electric apparatus; the crew lives aboard some of the boats altogether.

The French Government has been the most industrious in trying to use heavy oils for fuel for engines; in fact, abroad a number of Continental firms have been experimenting with the Diesel engine and have met with considerable success within the last few years. One government has proposed changing its gasoline engines for heavy oil engines, so well was it satisfied with their performance. Alcohol has not the same power as gasoline. When one attempts to provide a fuel which reduces power and speed, governments do not want it, so it looks

as if the heavy oil engine is the solution of the problem. Heavy oil engines are now so successful that Mr. Lake proposes putting them in his future boats, but he has never felt warranted in doing so heretofore.

Compressed air is not carried in submarines for the sole purpose of providing air for the crew, but for the purpose of handling water ballast, discharging torpedoes, and working certain machines. The Whitehead torpedo is discharged by compressed air.

All of our boats are provided with a buoy which may be released to the surface. The Russian buoy has information printed upon it in three languages, English, Swedish, and Russian, notifying the finders that there is a submarine boat below and asking them to open the buoy. When one does so, a telephone is found inside by means of which one can talk to the boat below. There is a whistle on these buoys, which is blown by compressed air, and a light can be turned on at night; they also have a tube by which the boat can be supplied with fresh air.

Mr. Lake knows of no practical method for vessels to protect themselves against submarines that has been proposed. The putting out of booms, he considers, would be no defence at all, because it would reduce the speed of the surface vessel using it. The only protection vessels have to-day against submarines is to get into a landlocked harbor and then have the harbor closed after them. The putting out of booms and heavy chain netting would not assist them because their speed would be reduced so that the submarine could approach them at will and go under the chain if necessary, or fire a succession of torpedoes and destroy the booms. The only safety for the pursued vessel is to put out to sea and get away if she knows a submarine is below. The torpedo will put any ship out of business, and a submarine can approach any ship to-day. The next war will without doubt prove that these little "Davids" are invincible.

The British Government has made experiments exploding gun-cotton and found that an explosion 20 feet away from the vessel would do her no serious injury, but an amount of gun-cotton exploded directly beneath a ship, even at 100 feet depth, would. Mr. Lake believes that a submarine would not be injured unless a mine were exploded right under her; at a distance of 50 feet away, it would not even rupture the hull.

The best speed for submarines, as far as Mr. Lake knows, is between 15 and 16 knots on the surface with gasoline engines. He thinks that will be increased considerably within the next few years.

Submarines are now built which have a submerged speed of 11 knots, and this will also probably be increased.

Mr. Lake has made experiments and has kept the hair-lines of the omniscope (which, by means of direction-indicating devices, aims the torpedo) pointed right on the stem of a vessel for a period of as much as five minutes at a time; that was actually done while a vessel was passing at a good rate of speed. The man at the observing instrument can check on his hair-lines and certain measuring devices the course of the vessel and correct the same. The difficulty is, will the torpedo run straight? Torpedoes are now made that will run up to 4000 yards.

Mr. Leavitt, who is the inventor of the torpedo of that name, suggests that it might pay with torpedoes used by submarines to increase the charge of gun-cotton and reduce the run. Mr. Leavitt sees no necessity for torpedoes which run over a thousand yards to be fired from submarines. Of course, when one fires at 4000 yards, the chances for making a hit are much decreased.

PAPER NO. 1090.

NOTES ON THE DEVELOPMENT OF THE MODERN IDEAS OF THE FORM AND POSITION OF THE EARTH.

HENRY LEFFMANN
(Active Member.)

Read April 16, 1910.

To write the history of any science, or even of any phase of scientific, religious, or political movement, involves several difficult duties. It seems as if one might apply to the task the form of dilemma by which a Greek philosopher argued that motion is impossible. He said: "A body cannot move in the place where it is, and it cannot move in a place where it is not; therefore, it cannot move at all." History cannot be correctly written by contemporaries of the events because they are too near to some of the occurrences and too much influenced by the passion and personal relations of the period, and it cannot be properly written by successors, because they are too far away to appreciate all the influences that determine the course of events.

Nevertheless, men will busy themselves with the history of the past, as well as of their own times, and with guessing at the future course of events, and under such an influence the author has taken up the task of indicating some of the points in the history of geography and astronomy which have been concerned in the development of the present generally received views as to the relations and shape of the earth from the crude and erroneous notions entertained by primitive man. An exhaustive treatment of this subject would require a good-sized volume and an elaborate study of authorities. The present paper is merely to set forth a few steps in the course of events. It must not be overlooked that some difference of opinion still exists among experts as to the exact form of the earth, some regarding it as slightly pear-shaped. Among the unlearned in civilized communities there are a few who still believe the earth is flat.

For many years it has been the custom of those writing on any theme of ancient history to turn first to the Greek and Hebrew

authorities. In many cases the records of other nations were obtainable only through these writings, for only a few fragments of Babylonian literature were available, and the extensive inscriptions in Egypt were unreadable. This has now changed. The industrious digging in eastern lands has yielded an immense amount of information, and the hieroglyphic writings are now easily read. In employing this new material, however, one must not overlook the fact that it has not yet been subjected to the minute textual and comparative criticism which has for centuries been applied to the literature of Greece, Rome, and Palestine. While the scholars at present studying the cuneiform and hieroglyphic remains are not few, yet one needs but to dip a little into the controversial literature to see that serious differences of opinion exist among experts, and that many of the translations may be altered at a later date.

Another point is often overlooked in applying the materials of ancient writers. It is customary to assume that the author represents his age, but this may be far from the case. Many examples might be given of this, but the point will, no doubt, be regarded as well taken. The preservation of ancient literature has been largely a matter of accident; that is, the destruction or preservation of a given document, monument, or tradition has rarely been dependent on the nature of the story involved, but largely upon the incidents of war, fire, or catastrophe of nature. Hence a particular manuscript may represent a minority opinion, or that of the writer alone, or, at most, of a few of his followers. A careful study of ancient literature will show that forgery and alteration were exceedingly common, and may be expected in the writings of any author, sacred or profane. The writings of ancient worthies have been interpolated without hesitation, and numerous treatises have been put forth fraudulently under the names of philosophers, teachers, monarchs, statesmen, and prophets. All the acumen of critics has not been able to separate wholly the false from the true. These practices have been so extensive and frequent that the author is satisfied to apply and extend the suggestion of Straus, that in judging of the writings of any ancient author, "a large allowance should be made for the hypothesis of conscious and intentional falsification." That so little prominence is given to this element of uncertainty is due partly to the "conspiracy of silence" which influences so many modern scholars, who fear that it will be dangerous to the public welfare to set forth the truth. In addition to these difficulties, the transcription of manuscripts, even

when the transcriber is honest, involves liability to error, and the significances of words change in time, so that, for example, no person can now read Shakespere intelligently without an elaborate commentary. The view one gets of the ancient world through the existing manuscripts, inscriptions, and traditions is comparable to Darwin's view of the value of the geologic record as an aid to the study of biologic history.

With these reservations as to the trustworthiness of the available sources, the author presents some of the data collected on the subject.

While evidence is now at hand to show the great antiquity of man, civilization, in the sense in which the term is commonly understood, dates back, as far as is known, only a few thousand years. References are occasionally made in the newspapers to civilized states of ten thousand years ago, but these figures are untrustworthy. It is, however, no longer permissible to doubt that the high development of life in Egypt and Babylonia dates back several thousand years before the founding of Rome. It is important to notice that the conditions at this remote period, as far as one can make them out, were not rude or half civilized, but a complex life, comparable in many respects with that of the most advanced nations of the present day. It may, indeed, be said that while the modern world has much more knowledge than the ancient, it has little more wisdom.

The Babylonian and Egyptian records now at hand show the oldest civilization known. The literature of those lands had a profound influence upon the literatures of Palestine and Greece, though to what extent is a matter of much dispute among the experts. The material has not been presented in such a form as to permit the general reader to judge of its value, or to give much information as to the views held by these ancients on the subjects under present discussion. In those days learning was largely, if not entirely, in the hands of persons who carried on the religious teaching. It is generally believed that the Babylonian and Egyptian priests observed the movements of the stars and had theories as to the arrangement of the universe. They recognized the distinction between the fixed and wandering stars. In a later period the Greeks applied to the latter the term "planet" ("wandering"), and this name has been retained in modern astronomy. At a very early period the lunar and solar cycles were recognized, and rude predictions of eclipses and occultations could be thus obtained. By this means also the calendar could be adjusted. The prediction of eclipses would greatly impress the mass of the people,

and it would be an easy step from this to establish the belief that the foreteller was also able to bring about the occurrence and hence could avert it. Thus would come the development of a priesthood, which would enforce authority, secure privileges, and establish the whole machinery of religion with which every one is so familiar—taboo, creed, sacrifice, and prayer.

The succession of the seasons would be easily learned by even the most ignorant, but the occasional irregularity of them might be the basis of much misapprehension and superstition. The times of marked seasonal change would become times of general public rejoicing or sorrow according as the event was joyous or otherwise. Thus, the beginning of spring, when nature begins to awaken from the winter quiet, would be joyous. There still is recognition of this in the Easter holiday. The winter solstice, when the sun, after several months of shortening its course, as if it were dying, begins to rise earlier and set later, would be hailed as a new lease of life for it, and we still celebrate this joyous event in Christmas season.

Much acrimonious discussion is now going on among students of oriental history as to the exact relation between the Babylonian and Hebrew theories of creation. It seems probable that creation-myths and theories as to the form, position, and early history of the earth were developing in southwestern Asia many centuries ago. The Hebrew story bears so many resemblances to the Babylonian that some evolutionary relation suggests itself. The two stories, however, suffered very different experiences. The Babylonian story ceased to develop. The people who held it underwent racial, religious, and national alterations, but the Hebrew story was carried onward by the evolution of a people that not only maintained for centuries their racial, religious, and national identity with much distinctness, but also refined and purified their theories of deity, and finally reached a high degree of monotheism, with coincident rejection of the nature-worship from which early religions took their rise. The consequence is that in the finished account as presented in the text of Genesis, the mythical element is minimised. The features in the Babylonian legends which seem fantastic are largely eliminated, so that the creation story in Genesis, though in some respects quite anthropomorphic, is attractive in its dogmatic tone and concise phraseology. When one recalls that the biblical story dominated thought absolutely in Europe for over a thousand years, one can see how difficult it was for independent scientific investigations to be made.

The Babylonians and Jews appear to have regarded the earth as a fixture in the universe and the sky as an attachment to it. The phraseology of the Hebrew text suggests this, and if one goes into the etymology, one can elucidate the matter further. The word "hashamayim," translated "heaven" in the English bible, is probably derived from "shama," which means "high." "Ha" is the definite article and "im" is the sign of plurality, so that the translation "In the beginning God created the high places and the earth" seems to give a meaning more nearly akin to that which the ancient writer had in mind than the modern translation "heaven," with its concomitant notion of the abode of deity and associated spirits. Similarly, the word rendered "firmament" is akin to a word meaning "rolled" or "spread out," conveying the notion that God spread out the substance of the high places.

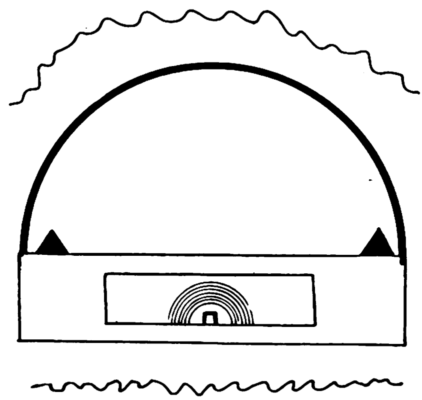


Fig. 1.—Babylonian conception of universe, adapted from Jensen, showing sunrise and sunset mountains, seven-walled abode of the dead; firmament, with waters above; waters under the earth

A graphic representation of the Babylonian theory of the universe is given by Peter Jensen in his work, "Die Kosmologie der Babylonier," from which the author has made a rude copy (Fig. 1). Jensen represents the surface of the earth as curved, but I think it more accurate to represent it as flat. By examining the text of Genesis, in the light of Jensen's picture, it is possible to construct rudely a representation of the universe as conceived by the Jews (Fig. 2), but it must be borne in mind that it is unlikely that either of these nations actually drew such pictures as are here shown. In the Jewish picture the attempt is made to show especially two of the meteorologic features, namely, the "fountains of the great deep," and the "windows of heaven." In Genesis vii : 11 the description is that at the beginning of the flood "were all the fountains of the great deep broken up and the windows of heaven opened."

These pictures must be regarded as suggestive only, but it is now

known that some attempt at graphic representation was made by the Babylonians, for a tablet has been found on which a rude map of the world is imprinted. As far as it can be made out, it seems to represent the earth as a plane surrounded by water—a not uncommon view, arising, of course, quite naturally from the fact that as far as the residents of Asiatic and European regions could go they were ultimately stopped by the sea or by ice.

Some of the Old Testament texts throw light upon, at least, the tendency of Hebrew thought as to the form of the universe. The vast plain of the earth is of circular shape—a view, of course, derived from the appearance of the surface when not broken by elevations. The waters surround the earth and reach to the circle on which the firmament rests. Thus, in Job xxiv : 10, "He hath described a boundary upon the face of the waters, unto the confines of light and darkness." In the eighth verse of the same chapter is the expression, "He hangeth the earth over nothing." Here seems to be a suggestion of a mass moving free in space. So in Proverbs viii : 29 it is said, "He set a circle upon the face of the deep." This circle is the visible horizon seen when one is upon water out of sight of land.

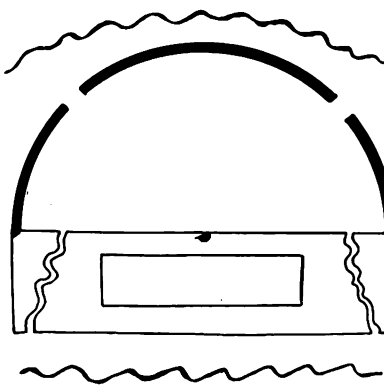


FIG. 2.—Schematic representation of cosmogony according to ancient Hebrews, showing firmament with windows of heaven; waters above the firmament; sheol, fountains of the great deep and the waters under the earth.

It is to be noted, also, that all the early cosmologies place the earth as an important feature of the universe, indeed, generally as the dominant one, but moderns know that it is one of the most insignificant parts. Each nation believed it was at the center of the earth's surface. The Jews thought Jerusalem was the center, a notion that was carried over into the Christian cosmology, and the Greeks thought that Delphos was the center, and consulted the oracle there.

Turning from these eastern lands to examine the science of the Greeks, one finds himself at once in the presence of a philosophy different from oriental thought. Imperfect as were their methods

compared with present ones, the Greeks were the only scientists of antiquity. They alone felt the influence of nature as the manifestation of materialistic forces; they alone subjected all phases of knowledge to searching investigation. Their known history does not go back nearly as far into the past as that of the oriental nations, and they probably derived their language, much of their religion, and some of their fundamental ethical and philosophic doctrines from the orient, but they transformed all this material and brought out of it much that was new.

The Greek philosophic literature of the seventh, sixth, and fifth centuries before the Christian era is unfortunately only known in fragments, principally as quotations in the writings of later authors, one of whom, Aristotle, was essentially hostile to their views. It appears that materialists of the present day could shake hands over the interval of two thousand five hundred years with the early Greek thinkers. The discussion of philosophic theories did not lead to the recording of much astronomical data; at least, none has been handed down; so one is not able to determine the exact views of these pioneers. It is stated on good authority that in the seventh century B. C. Thales predicted an eclipse, but he may have been in possession of records that showed the approximate periods of recurrence.

Anaximander (580 B.C.) was one of the first to teach that the earth is free in space; it appears that he regarded it not as spherical, but rather flat-cylindrical, that is, drum-shaped. Pythagoras (about the same date) and his followers taught the sphericity of the earth. Anaximander is said to have made the first map, but this can only apply to Greek history, as some very early Babylonian and Egyptian maps have been found. It is doubtful if Herodotus accepted the theory of the sphericity of the earth, but Aristotle taught it. How far the doctrine was accepted outside of the philosophic circle it is impossible to say. The ancient philosophers concerned themselves but little with the proletariat and slaves who formed the bulk of the working class.

The Romans were too busy conquering the world and attending to the government of it to develop the sciences to any great extent, and they took much of their knowledge and methods from the Greeks. Pliny the elder, in his work on natural history, is very positive as to the sphericity of the earth, devoting a chapter to arguing that there may be antipodes, adducing such facts as the observed curvature of the sea and that drops of water on a dusty surface assume a

spherical form. Pliny's discussion, however, shows that the sphericity of the earth was not universally accepted in his day, and as it is unlikely that a Roman of his social standing would concern himself with the opinions of the mass of the people, it seems probable that a belief in a flat earth was found among the patrician class. It may, however, be assumed, I think, that at the period when Christianity began to be preached to the Greek and Latin pagans, a wide-spread belief existed among them that the earth is round and is not the center of the universe, though doubtless the latter view was less generally accepted than the other. The demonstration is more difficult. Even with all the resources of modern science it would be difficult to convince a stubborn, ignorant person that the earth rotates at such a rate that the surface velocity is about a thousand miles an hour.

The question at once arises why, if correct views were so widely taught in pre-Christian times by influential writers, and were generally though not universally accepted, the views were abandoned and the world for over a thousand years given over to erroneous theories. The change is to be ascribed to the influence of the Christian fathers. In the first three centuries of the Christian era this influence was mostly operative in the regulation of church discipline and doctrine and in antagonism to the immoralities of pagan life; but when the victory over paganism was assured, they applied their energies to eradicating from the minds of converts all traces of pagan philosophy, ethics, and science. Everything taught by the Greek and Roman philosophers was alike tabooed. In this process the language of the Hebrew texts would lend assistance, although the allusion to the standing still of the sun and moon does not prove a belief in the geocentric arrangement of the universe, for one still uses the same forms of expression, speaking of the sun's rising and setting and of the moon entering the earth's shadow during an eclipse, all of which expressions are inaccurate from the point of view involved in modern theories.

By the end of the twelve hundredth year of Rome, corresponding to the middle of the fifth century of the common era, paganism had been suppressed, the great empire of the Cæsars had begun to disintegrate, and Europe had entered upon that period of stagnation that was to last a thousand years. A glimmer of scientific spirit developed in Spain under the Moorish dominion, but its brilliancy has been overrated. It is now known that some of the manuscripts

purporting to relate discoveries in sciences, notably chemistry, are forgeries of much later date. What this spark of learning might have become under the influence of a long peace and the establishment of an empire on Semitic principles no one can say, but when the cross took the place of the crescent on the towers of the Alhambra, the last light of Europe went out.

The history of the period intervening between the fall of paganism and the revival of learning in the fifteenth century is yet almost unwritten, except as the bald records of wars, disasters, and persecution. As has been aptly remarked by Macaulay, the human race ceased to march; it merely marked time. As far as philosophy was cultivated, it was bound in narrow limits by the influence of the church on one hand and by a slavish devotion to Aristotle on the other. Learning retreated into the monasteries, and flourished but feebly in many of these. Benedict, who founded the order that bears his name, did much for the preservation of literature, for it was one of the statutes of the order that each member of it should spend some time each working day in the writing-room of the residence. The libraries of the Benedictine convents have yielded many most valuable treasures of ancient literature. In the Benedictine convent at Monte Cassino, near Naples, founded by Benedict himself in the sixth century, is to be found the best and oldest manuscript of the account of the water-supply of Rome, by Sextus Julius Frontinus, who was Water Commissioner of Rome from 97 to about 103, under Nerva and Trajan. This is a unique relic of ancient engineering.

Some glimpses of the dark ages might lead one to believe that learning was at times fairly active. Thus Hume states that in 1344 many hundreds of students attended the University of Oxford, but that they studied only bad Latin and worse logic. In the same year Pope Clement VI made a grant of jurisdiction, but the learned councillors at Rome knew so little of the geography of the shores of western Europe that in the bull, the Canaries were confused with the Azores.

It was in 1453 that Nicholas Koppernigk (Latinized to Copernicus) published his epoch-making work, in which he maintained the view that the earth is subject to a diurnal motion of rotation, and revolves in an orbit of which the sun is the center. A complete system of astro-physics was not, however, set forth by this astronomer. Among the difficulties that retarded the development of correct notions was want of knowledge as to the distance of the fixed stars. The immense

distances at which even the nearest of these are placed are not evident by ordinary study of the heavens. In the old Ptolemaic system, the fixed stars were supposed to be arranged upon the surfaces of transparent spheres which rotated. As only the few planets showed any relative change of position through the year, it seemed impossible that the earth could be moving in an orbit which caused a translation through space; but it is now known why, even though the earth traverses an ellipse of which the long diameter is about 180,000,000 miles, the relative positions of the majority of stars change so slightly that only the most delicate measurements will show it. It is because even the nearest stars are so far away that the two sides of the isosceles triangle formed by the lines directed from the opposite points of the earth's orbit are sensibly parallel. Some idea of the distances involved may be gained by the following comparisons. If the earth is represented by a globe one inch in diameter, the sun will be represented by a globe about nine feet in diameter, 1000 feet distant, and the nearest fixed star (alpha Centauri) will be 100,000 miles away.

Not long after Copernicus, Tycho Brahe, a Danish astronomer, took up the work. He, however, did not advocate wholly the view of Copernicus, but taught that the planets, except the earth, went around the sun, and that the whole universe went around the earth. Johann Kepler placed the subject on more satisfactory ground, when he pointed out that the orbits of the planets are not circular but elliptic, with the sun in one of the foci. The invention of the telescope marked an important advance, for it now became possible to determine that the known planets are near enough to show appreciable disks, while the fixed stars are so distant as to show no disk. It is to Galileo Galilei that the early application of the telescope in astronomy is due, and he forcibly advocated the doctrine of the diurnal motion of the earth and its movement around the sun. It is in consequence of his somewhat active propaganda of these doctrines that one gets a brilliant light upon the trend of opinion of those times. In 1615 Galileo's doctrines were formally denounced by the authorities of the Roman Catholic church in the following terms: "The proposition that the sun is the center of the world and immovable from its place is absurd, philosophically false, and formally heretical because it is expressly contrary to the Holy Scriptures.

"The proposition that the earth is not the center of the world, nor immovable, but that it moves, and also with a diurnal motion,

is also absurd, philosophically false, and, logically considered, at least, erroneous in faith."

It is to be noted that at the present time no astronomer considers the sun the center of the universe, for the word "world" in the above translations from the Latin text of the decree must be so understood.

In 1633 Galileo was compelled to abjure formally his doctrines. It is said that as he rose from his knees after the formal renunciation he added, in Italian, "and yet it moves"; but this is doubtless a poetic gloss.

The aid given by the telescope and accurate methods of observation rapidly extended knowledge, and before long all educated persons held the current opinion, but conservatism dies hard, and it was not until after the beginning of the eighteenth century that a book giving the heliocentric theory of the solar system was permitted to be published in Rome.

The discovery of the principle of gravitation, the application of the spectroscope, and the employment of the pendulum as a means of demonstrating the rotation of the earth are among the advances that have placed on a secure basis our knowledge of the near portions of the universe, and indicated, in a general way, the character of the whole visible cosmos. Modern astronomy is more properly designated, as is now usual among experts, as astro-physics. The phenomena of planetary motion are merely illustrations of the principles of mechanics. It is not possible to satisfy the human mind, and much activity is now shown in investigating the problems of the origin and destiny of the universe, but one would be led too far afield if one was to attempt a determination of the relative merits of the nebular or planetesimal hypothesis, or to criticize the untrustworthy and misleading statements of Lowell as to life in another world.

PAPER NO. 1091.

CONSTRUCTION OF A RAPID TRANSIT RAILROAD IN RELATION TO THE HANDLING OF PASSENGERS, AS ILLUSTRATED BY THE HUDSON AND MANHATTAN RAILROAD.

J. VIPOND DAVIES.
(Visitor.)

Read June 4, 1910.

PASSENGER transportation has developed the most complex problem which is to-day presented to the engineer for solution. The immense increase of population, particularly with reference to the concentration in cities, has produced new and grave conditions which have to be cared for by a careful study of individual cases, as each case requires absolutely new and independent treatment. With the steam railroads the problem of handling passenger traffic remains very much as it formerly did, except that with the extension of cities into their suburban districts the local traffic has become so much heavier that the distribution of passengers from the terminal destination introduces a new and serious problem. The number of persons who desire an all-the-year-round residence in the country districts, and who conduct business within the cities, is becoming yearly greater, and is only made possible by improved transit facilities being provided. This condition has also become a considerable factor in increasing the taxable values of suburban real estate and in developing real estate in the suburban districts of the great cities. London and New York offer the best illustrations of this condition, as in each of these cities, there is a small district of limited area in which the bulk of the business is transacted, and a huge territory, radiating in every direction, where the business people have their residences. The state line between New York and New Jersey is a fictitious division; and, eliminating all consideration of the boundary-line between these two states, there is a district tributary to New York City which has a total population of over 6,500,000 persons.

In a community of this character the nearer one gets to the center of the city the more dense becomes the traffic, the need for increased transit facilities greater, and the possibility of movement slower, all on account of the great concentration and the interference of cross-streams of travel. Every one is familiar with the fact that for reasonably short distances within this zone of density one can reach his destination quite as quickly by walking as by using a surface car. As one gets farther from the center of a large city and approaches the country, the traffic thins out, proportionally with the density of the population, and at the same time the possible speed of transportation becomes greater. The latest figures available indicate that the total movement of passenger traffic within the metropolitan district of New York aggregates very close to 2,000,000,000 people per annum on all lines, which is equivalent to 308 rides per capita per annum, and the movement of passengers within the Borough of Manhattan averages over 400 rides per capita per annum. In order to get more rapid service for passenger traffic it has become necessary in New York to move the means of transportation from the surface of the streets, where there is interference with every other class of vehicular and pedestrian travel. As a city grows to the size which is now known as a city of the first class, these conditions arise, the necessities become similar, and gradually the large cities are forced into doing what New York is doing at the present time, viz., to install transit lines either above or below the surface, so that rapid transit service may be carried on without interference with other transportation and thereby obtain a greater measure of rapidity and safety in the service. In the city of London this condition arose many years ago, earlier possibly than would be the case in most American cities, on account of the narrow streets and the consequent tremendous surface congestion. With broad avenues or streets the period of congestion is postponed, so that the necessity for transit lines either above or below the surface is not reached at quite as early a period in the growth of a city. Our great cities are not willing to develop elevated railroad lines anywhere near their hearts, on account of obstruction to light and air, the further and serious obstruction to other traffic, and, what is by no means the least objection, the great nuisance of increased noise, so detrimental to the nervous systems of people who must hear the roar of the traffic. At the same time in many of the American cities elevated railroad lines are deliberately, and it seems foolishly, installed in the suburban districts purely on the ground of

the cheapness with which they can be constructed, or in order to obtain what is called rapid transit service at a reasonable cost, in districts sparsely populated. This has been deliberately done with the present Rapid Transit Subway in the city of New York, where, in the northern portions of the city, the subway emerges onto an elevated structure and runs over long sections of steel viaducts. To a considerable extent the same has been done in Philadelphia. If any such structures are necessary and are hereafter built, they should be carefully designed and constructed so as to eliminate all noise arising from an exposed light steel structure. This may be accomplished without any great addition in first cost, and with only slightly increased obstruction upon the surface of the ground.

The title which has been adopted in this country for transportation other than on the surface has an unfortunate adaptation, as it involves a good deal of service which is by no means "rapid transit." The service to which these or any lines of public transportation are applied is affected materially, first, by the density of the population, and, second, by the local conditions. At the same time it is readily understood and appreciated that the service is the heaviest at certain hours of the day and lightest at other hours, and, curiously enough, it seems that on most lines the traffic curves correspond very closely; that is to say, granting a certain total daily service given by any line of railroad, whether on the surface, on ferries crossing the rivers, on an underground, or steam railroad line which does a local transportation business within our populous areas, the curves of traffic per hour are very similar, varying, of course, according to the total movement per diem. These curves reach their summit, or peak, in the morning hours in the movement toward the heart of the city between 7 and 9 o'clock, and reach the corresponding peak for the evening outward bound movement between 4.30 and 6.30 o'clock. The Public Service Commission has rather happily designated these movements as "workwards" and "homewards" respectively. The morning peak in one direction, workwards toward New York, reaches its maximum between 8 and 9 o'clock, 7½ per cent. in the direction of heavy flow, and in the opposite direction simultaneously 1½ per cent. of the entire total traffic in both directions per twenty-four hours; while the homeward peak in the evening—the heaviest and controlling movement—reaches its maximum between 5 and 6 o'clock, when the outward movement is 10.7 per cent., and the simultaneous reverse movement 2½ per cent., of the entire total traffic in both directions

for the day. The movement during the middle of the day is very much less, while the movement after midnight is extremely light, and no railroad operates suburban trains at a profit during the wee small hours of the night, but only on account of its general obligation to the public.

The Hudson and Manhattan Railroad Company was organized as a private enterprise, and as an interstate railroad to handle a proposition which is new and unlike any other in New York city or elsewhere. As every one is well aware, the steam railroads handling New York traffic terminate for the most part on the west bank of the Hudson River, whereas the destination of the passengers is almost entirely within the city of New York. Similarly the street railroads have their termini at various points along the Hudson River front, and a very large portion of the traffic is carried from points in New Jersey to these termini for ferriage across the Hudson River to New York City. The Hudson and Manhattan Railroad differs therefore from the ordinary rapid transit railroad in that it is a terminus in the city of New York for the steam railroads terminating in the State of New Jersey, and is a collecting agency in the city of New York for passengers using the steam or surface roads from Jersey City and Hoboken to the suburban districts in New Jersey. The layout of this railroad is now so well known that it is unnecessary to elaborate upon it, except to draw attention to the fact that the road has in New York both an uptown and a downtown terminus. The former is located in the shopping district and is convenient to places of amusement, hotels, and the residential district, and the latter is in the heart of the financial and business district. For a road having the short mileage of the Hudson and Manhattan Railroad the traffic concentration is very great, in fact, as great as on any railroad in the city of New York, and in studying the proposition of construction and operation it has been necessary to consider carefully the very great concentration of traffic, and consequently to arrange all the details of construction and equipment for easy, prompt, and efficient handling of the public.

There is no one who will disagree seriously with the statement that the public, taken *en masse*, is like a flock of sheep, extremely difficult to direct or handle; and that it will at all times move in what it considers the lines of least resistance; consequently the public moving as a mass is a very serious problem to be considered by those designing or equipping a transportation line. The treatment of such a proposi-

tion must be done with a clear knowledge of the fact that one is dealing not with individuals but with masses or crowds; and while the individuals composing the mass have sense and can be reasoned with and managed, the mass is unreasoning and often unreasonable; consequently nothing can be omitted in the design and equipment of a transportation line which will assist and direct a crowd so that it can have no possible choice in the matter of what it will or will not do. Only by perfect arrangements in this respect can the railroad and its operating officials obtain the best results for the traveling public. To obtain best results has been the constant effort of those who have had to do with the development of the Hudson and Manhattan Railroad.

The original inception of the present system was a tunnel between the foot of 15th Street, Jersey City, and the foot of Morton Street, New York, which had been started many years ago. The Company had undergone several reorganizations, and the property was finally acquired by the present holders at a foreclosure sale. The property then consisted of a section of a tunnel, of considerably larger internal diameter than the present tunnels, driven from the New Jersey shore toward New York. It was designed and partially constructed with the idea of being a terminus to be used jointly by the Erie and Lackawanna Railroads, and while the construction of this short section made history in engineering, considering that the promoter was really not an engineer at all, the use and operation of it were utterly impossible. The portion of tunnel constructed was 18 feet internal diameter, unnecessarily large for the ordinary street railroad or suburban railroad car, but too small for two cars to pass, and yet the tunnel was designed for a standard steam railroad car, for which it was unsuitable. In the first financing it was most essential to get a tunnel under the river to demonstrate the feasiblity of its construction, and after the long history of failure which had attended the early days of the Hudson River Tunnel Company, it was desirable to establish the fact that such a railroad could be built and operated. A plan was therefore prepared by which it was contemplated that the tunnel would be carried to the New York shore of the same diameter as the portion driven from the New Jersey shore, and within this tunnel it was proposed to operate very narrow cars, somewhat along the lines of the cars first operated in the City and South London Railroad tunnel in London. The tunnel was to be equipped with double tracks and operated as a double-track railroad, in order that it might be of

some service to the public and at the same time prove the feasibility of its construction and operation. This plan also contemplated adhering to the original location of the road, which provided for a terminal on the surface about midway between the Erie and Lackawanna Railroad stations in Jersey City. It was proposed to divert the street railway cars to this terminus, making it necessary to transfer passengers across a platform from the street railway cars to the narrow tunnel cars and vice versâ. In New York it was planned to have the narrow tunnel cars come to a depressed station at Christopher and Greenwich Streets, making the terminus at that location adjacent to a surface car line in New York. Such an operated tunnel would have simply been a connecting link between the street railroads in Jersey City and Hoboken and the street railways in New York. It was very easily proved that such a proposition, operating narrow cars as individual units, would not be sufficient in capacity or rapid enough to handle the traffic, and could not earn sufficient money to pay the interest on even the comparatively small capitalization necessary to complete, equip, and put in operation the double-track railroad in the single tube. The next step was to complete a second tunnel with similar termini, making a double-track railroad, through which could be operated standard street railway cars. Such a proposition would not be feasible, as no one operating a tunnel railroad of this character would agree to operate it with anything but cars of steel and fireproof construction. With the use of such cars no speed could have been attained except by coupling the cars and forming trains. The undertaking proceeded on this general idea, but it was planned to construct the street railroad cars of steel and to couple them into trains and operate such trains through the tunnels with a full system of signals. The second tunnel was designed not only to take street-cars, but also larger cars, if later on it were found desirable to equip the tunnels with larger cars for regular suburban service. It was found that the termini as contemplated were poorly located for convenience of public service and quite inadequate and insufficient for practical use in handling a volume of business large enough to insure getting returns from the capital necessary; and considering that a public utility is primarily for the public use, it was decided not to spare any expense and to overcome all difficulties so as to make the project of the greatest service to the public. The terminus in New Jersey was the first one changed, and the location adopted was at the Lackawanna Railroad terminus in Hoboken, where all the

surface and trolley lines of the Public Service Corporation of New Jersey from the north end of Hudson County terminate, and where the Lackawanna Railroad brings a large suburban traffic over its lines. When the first tunnel was connected under the river to New York, application was made to the Rapid Transit Railroad Commission for authority to change the location of the terminus in New York, for which the earlier franchise had been obtained, to a point where it would be of real service to the public as well as an objective point for operation. The result was the location of the terminus at Sixth Avenue and Thirty-third Street.

Such is the brief history of the development of the Hudson and Manhattan Railroad, and it may be of interest to present various points which have been carefully studied, considered, and adapted for its particular business and special needs, whereby the company has endeavored to carry out arrangements which place this road, it is believed, ahead of all others that have been installed in combining convenience and ease of operation with the least possible friction and discomfort to the traveler, and with the greatest possible efficiency and economical handling of traffic.

Capacity.—The first essential in the study of this railroad was to decide definitely on the capacity for transportation that could be furnished during the hour of maximum travel, as this factor is the basis for regulating everything that comes after. The dimensions of the property which could be acquired for stations, either downtown in New York or at Hoboken where it was necessary to locate upon private property and not under the public streets, fixed the greatest length of train that could be accommodated at 400 feet. The curvature of the railroad as laid out, particularly the short curves (radius 90 feet) entering and leaving the Church Street Terminal, made it necessary that the cars should be as short as possible and the truck centers so spaced as to reduce the overhang of the cars on curves to a minimum. The cars in the Rapid Transit Subway in New York are 52 feet long, but this length proved to be too great for the Hudson tunnels, as an eight-car train would be in excess of the maximum length of train that could be accommodated on a tangent in the stations. After considerable study the length of car determined was 48 feet 3 inches when coupled, with distance between truck centers 33 feet. All clearances in the tunnels and approaches had, therefore, to be figured in relation to this particular size of car. The clearances in the tunnels allow for a car of the same width as the original subway

cars (8 feet 10½ inches), which makes a roomy car, satisfactory for passenger use. The height of the car, which does not affect the comfort of passengers, was of necessity made low on account of the clearances. The length of train determined upon was eight cars, a total length of 386 feet. A speed curve diagram was then calculated on the fixed characteristics of the railroad, the train weights, and on the assumption that motor equipment would be installed on the cars to operate at a maximum speed of 45 miles per hour on level tangent. The speed is reduced for station and junction controls, on curves, and, of course, on grades. It was figured that station stops would be thirty seconds. Experiments with the air-brakes determined the safe braking distance on various grades throughout the tunnels at which the cars loaded and operated at the calculated theoretical speeds could be properly controlled. The safe braking distance determined the spacing of signals, and as the signal system is the double overlap type (that is to say, the position of a given signal ahead is indicated to an approaching train at two signal stations previous) the spacing of signals throughout the tunnels provides for the closest possible operation permissible under ninety seconds headway with eight-car trains. The railroad is being operated on this interval successfully and regularly. The train load and the minimum train interval indicate that it is possible to operate any portion of the road to the extent of carrying 32,000 passengers in one direction in one hour. All the remaining factors entering into the design of a railroad operated for passenger service depend, therefore, on this one essential prime factor—maximum capacity.

Stations.—As in almost every road laid out, the general location of stations is one of the easiest matters to decide upon. The questions involved are what points offer the greatest facility for the collection and distribution of passengers, and how frequently stations should be located. In this particular case the solution was even more simple than usual. A terminus downtown in the heart of the business district was essential, and its general location had to be within quite narrow limits. The exact location was fixed by the property which could be acquired near Broadway, between Fulton and Cortlandt Streets. The short length of, and the physical conditions on, the downtown line led to the conclusion that there would be no station but the terminal, and as arrangements had already been made with the Pennsylvania Railroad for a connection and for interchange of business, the first station in Jersey City was obviously under the

station and tracks of the Pennsylvania Railroad. At Hoboken arrangements previous to this had been made for the occupancy of the under-surface of property of the Public Service Corporation at the point where its trolley system terminates near the ferry; and fortunately this location was adjacent to the Delaware, Lackawanna and Western Railroad station, so the use of this private property fixed the station at this point. The tunnels extending from Hoboken to the Pennsylvania station pass under the property and yard of the Erie Railroad, so a station was located at Pavonia Avenue for the interchange of passengers with the Erie Railroad and also with the trolley cars of the Public Service Corporation. These points practically control all the local street railroad business of Jersey City and Hoboken as well as the great bulk of the steam railroad business coming to New York.

In New York city uptown the local conditions make it necessary to have stations at close intervals to give proper facilities to the public and to connect with the intersecting street railway lines, elevated railroad lines, etc. It was undesirable to locate stations, even for local business, closer than 1200 to 1500 feet, which makes but a short distance for passengers to walk to or from intervening points, and if the stations were located closer than 1200 feet the trains could not gain sufficient speed between stations to give adequate service. In the case of Hudson and Manhattan Railroad the stations, except on Sixth Avenue, are few and at long intervals. The distance from Church Street to the Pennsylvania station is 1.25 miles, from Hoboken to Christopher Street 2.01 miles, and from the Pennsylvania station to Hoboken, with only one intermediate stop—Erie Station—is 1.75 miles; consequently very fast service can be given.

Having decided upon the general location of the stations, the next point was to determine upon a design for stations with a view of providing every facility and convenience for the traveling public. When a railroad has to provide facilities for handling a concentrated travel of 32,000 passengers per hour in one direction, and when that volume of traffic is likely to have one point as its destination, as, for instance, Church Street Terminal, New York, and to a less extent the terminal at Hoboken, then the design of the station is all-important, and it is particularly important with respect to regulating the length of time of station stops, so as not to hamper operation and interfere with the regular maintenance of the prescribed train interval. Some years ago it was thought necessary by railroad men to have at a station

a large number of tracks where trains could stand a considerable time while being unloaded and loaded. The conditions of suburban rapid transit service have necessitated a radical change from this old theory. A steam railroad train made up of coaches equipped with platforms and steps at the ends by which passengers must leave and enter can only unload and load, even in the most rapid suburban service, at the rate of approximately 30 passengers per minute per car. For steam railroad trains with cars having a seating capacity of about 60 passengers, and no necessity whatever for making a short station stop, this rate of handling passengers is still permissible; but with rapid transit service, where it is not unusual to have a total of 115 passengers per car, this rate would be impossible. Cars equipped with end doors at the level of the station platform, as in the older types of elevated and subway cars, permit the movement of only one person through a car door at one time. It requires sixty seconds to unload a car of this type, and if the train is then reloaded at the same point, it requires thirty seconds to take on, say, one-half a carload. As the movement in the contrary direction is never as heavy as the movement in the maximum direction, and as the loading process cannot be begun until the unloading is completed, it is obvious that this interval would be prohibitory under conditions of maximum service. Further than this, the fact of having a single platform from which to unload and load passengers simultaneously introduces a congestion on the platform which delays materially this movement and lengthens the necessary station stop. Even the movement on street-cars in or out is only at the rate of 50 passengers per minute through end openings, and if one end is closed, as in some of the modern cars of the pay-as-you-enter type, when operated at terminals it is not unusual for passengers to enter at a rate of only 17 or 18 persons per minute, and consequently to get a car loaded at such a slow rate as this interferes materially with the capacity of the road.

At the Hoboken Terminal the Public Service Corporation has lately completed a terminal station, which is a new departure and ideal for handling efficiently these types of cars. The station is inclosed, and every passenger must buy a ticket and put it into a chopping-box before entering the station; the conductor has only to collect fares from passengers who get on after the car has left the terminal station. In street service passengers usually get on or off in small numbers at any place other than terminals, and so if these terminal points are cared for, there is little difficulty in handling the passengers.

The result of numerous observations of all possible combinations shows clearly that the essential requirement of all station design for handling large crowds at terminals is to separate the movement of passengers so that cars are unloaded from one side and loaded from the other. This does not necessarily apply at local stations, where passengers are comparatively few and well distributed; the movement can be made within the allowable thirty-second station stop and with comparatively little inconvenience to the public. The Church Street terminal (New York), Hoboken terminal, and the stations now being constructed at Thirty-third Street and Broadway, New York, and at Summit Avenue, Jersey City, therefore, are arranged with platforms at the level of the car floor and with provision for loading trains from a platform on one side and unloading onto a platform on the opposite side.

The next point to be considered in designing the station is the arrangement for handling passengers between trains and public thoroughfares without conflict in the movement. It is most essential in any railroad proposition to control the movement of passengers as far as possible in the right-hand direction, and so far as possible to deliver the flow of passengers in one direction at points where they will not come in contact or conflict with the passengers moving in the opposite direction. One of the most unfortunate features in an underground system is the necessity for taking passengers from station platforms below the level of the street and distributing them at the street surface, and this necessitates in the cases of slight elevation stairs or ramps, and in cases of great elevation escalators or elevators. The movement of passengers in a straight passage, either on a level or on a reasonable incline of 10 or 12 per cent., is very rapid, and when the movement is approximately in one direction, it amounts to 40 persons per foot of width of passage per minute. Consequently a comparatively narrow passage will accommodate a large number of people in a short period of time. As soon as such a movement reaches a staircase, however, the rapidity is immediately reduced, as the step taken by the passengers is shortened from about 30 inches to approximately 12 inches, so that while the passenger may take the physical step as rapidly as when walking on a level surface, the actual forward movement is perceptibly slower. On broad staircases, moving in one direction only and upward, the number of passengers per minute averages 15 per foot of width, whereas the maximum counted on any staircase under these conditions is 24 per minute. If moving down-

ward, the average per minute under similar conditions is 13 and the maximum is 18. These conditions have to be taken into serious account when the necessity for staircases arises. It is equally obvious that wherever conditions permit, ramps should be provided instead of stairs, as the accommodation provided by a ramp is very much greater and the use of a ramp is materially easier for the passenger.

In the development of Church Street terminal, where the concentration of people is likely to be excessive, there could be no choice in the use of staircases for handling passengers from the platforms to the concourse level, but the height of the concourse above the platforms was made as small as was possible, allowing proper clearances for the trains. The alternate platforms in this station are for loading; the others for unloading, so that the loading platform serves two trains, while the central unloading platform serves two tracks; the exterior platform is for unloading and, of course, serves but one track. The arrangement of staircases from the unloading platforms is tandem on the centers of platforms, and the direction is outward from the center of the platform. There are six staircases to each platform,—three on each side of the center line of the platform,—so that the distance from the exit door of a car to the nearest staircase is very short. These staircases discharge passengers at the concourse floor in a direction pointing south to Cortlandt Street or north to Fulton Street, thus delivering passengers on the concourse floor in the direction they desire to proceed. On the other hand, the staircases to the loading platforms lead from central points on the concourse floor to points along the train platforms, and are so arranged that each loading platform has two pairs, which enables the operating department to group the chopping-boxes at the top of each of the two pairs of staircases and thus reduce, during the slack hours, the expense of ticket-choppers, ticket examiners, guards, etc. Up to the present time no more efficient arrangements have been invented for examining and canceling tickets than the old barriers and chopping-boxes. The arrangement of stairs delivers passengers coming to trains at four points on the loading platforms more or less equally spaced, and provides an equal distribution in the train loading. At the Church Street terminal the space is sufficient to permit of distributing passengers on the concourse floor, so that under the worst conditions of the maximum traffic there will be no congestion on this floor, and the extremely broad ramps to Cortlandt and Fulton Streets and wide

staircases to Dey Street provide free ingress and egress to and from the concourse floor.

It is not possible in all cases to load passengers so that they will be evenly distributed throughout the train, as is the case at Church Street terminal. For instance, at Hoboken terminal the only connection available for interchange of passengers with the Lackawanna Railroad is at the extreme easterly end of the platform, and naturally most of the passengers from the Lackawanna Railroad enter the first car they come to and fill the cars at one end of a train, leaving the cars at the other end practically empty. To counteract this unequal train loading an entrance for passengers interchanged with the Public Service Corporation (trolley cars) was constructed as near as possible to the other end of the station, and the result is a well-balanced arrangement for the distribution of passengers throughout the entire train. Similarly, at the Pennsylvania station passengers from the railroad are necessarily delivered to the Hudson and Manhattan Railroad at the extreme easterly end of the station, and to counterbalance this, entrances for passengers from the trolley cars and street are located at the westerly end of the station. The local stations on Sixth Avenue have all been arranged with entrances and exits as near as possible to the center of the train, whereas the stations at Christopher Street and Ninth Street, owing to curves in the line which prevented the platform from being centered on the only available site for a stairway and entrance, are arranged for end loading—Christopher Street at the westerly end and Ninth Street at the easterly.

In the design and construction of the stations of the New York rapid transit subway practically all the entrances and exits consist of openings in the sidewalks covered by kiosks, which interfere seriously with the use of the sidewalk. In the development of the Hudson and Manhattan lines the Rapid Transit Commission appreciated the objections to the kiosks erected on the sidewalks and compelled the company to arrange for the entrances and exits through private property unless specifically permitted to do otherwise by the Commission. In some cases arrangements were made for entrance and exit through private property on Sixth Avenue, and in other cases entrances and exits were placed under the stairways leading to the elevated railway, so that the erection of kiosks involved no additional obstruction on the sidewalk. To make a railroad of the greatest convenience to the traveling public, the stations need be clearly

defined and easy of access. An entrance through private property seldom affords the same convenience to the public as does an entrance direct from the public streets, even at the expense of obstructions such as railings or kiosks. Entrances placed directly upon the street are more in evidence, and are consequently of greater value to the public, so that although, at first thought, the obstruction to the sidewalk may be considered as preëminent, yet the general convenience of the traveling public is better served by kiosks. On the other hand, where it is possible to arrange stairways, as was done on the Hudson and Manhattan Railroad, under the stairs of the elevated railway, so as to provide this convenience without additional obstruction to the sidewalks, the arrangement is ideal. There is, however, one serious drawback, as in the majority of cases the stairways to the elevated railway are so narrow as to give inadequate width for proper service, and wherever there is a possibility of passengers moving in opposite directions no stairway should be installed less than five feet in width, and it is desirable to make them not less than six feet wide, which allows ample width for two persons abreast walking in the direction of the maximum movement and one person in the direction of contrary movement. The interference with the movement of passengers in the maximum direction by an opposite movement on narrow staircases is detrimental to general efficiency.

Platforms should be designed to provide ample room for the free movement of passengers. In the case of unloading platforms all that is necessary is to have sufficient space with ample exits, so that an entire trainload of people can be easily discharged onto the platform within the limit of time fixed for the station stop, and, further, that the entire trainload so discharged may pass out of the station before the arrival of the following train. It is usually not necessary for a platform to be wider than the floor area of the car itself, although there should be a widening of platforms in the vicinity of the stairways or exits, as there must of necessity occur a slight congestion at the points of exit from the unloading platform. In the case of loading platforms, the consideration is affected materially by the character of train service operated. With the Hudson and Manhattan Railroad at Church Street terminal, and later at the Thirty-third Street terminal, there are in use platforms 20 feet wide, common to trains serving different routes. There must, therefore, be ample room on the platforms for an entire trainload of people to stand for either route for which a train is destined and to distribute themselves so that

they can enter the train immediately upon its arrival. It is obvious that if an attempt is made to unload passengers from an arriving train onto the same platform on which passengers waiting to leave on the same train are standing, the movement of passengers is seriously interfered with and the public inconvenienced, since the station stop must be increased to permit loading and unloading of the trains. It is very plain, therefore, without argument or the use of figures, that the convenience of the public and the rapidity of passenger movement can be best accomplished by unloading passengers onto one platform and loading them from another. It is quite material in unloading passengers that the train stands on a tangent. The great objection to a train standing on a curve at a station is that passengers may be injured by stepping through the gap between the train platform and the station platform. In the Rapid Transit Subway in New York, as well as elsewhere, this gap has been illuminated by lights underneath the edge of the platform which clearly indicates the gap, and assists materially in avoiding accidents, but, apart from the possibility of accidents, the location of a station platform on a curve, with the consequent gap between the platform of the car and the station platform, seriously affects the rapidity of movement of passengers either entering or leaving the train. There is an instinctive pause by each individual seeing the gap; the movement is much slower in consequence, and the length of the station stop is materially lengthened.

The arrangement of ticket offices is important in station design. At first sight this seems like a matter requiring little attention, but as a matter of fact it is essential in the economical operation of a rapid transit railroad and in the efficient handling of passengers. In arranging ticket offices it is vitally important to locate them so as to force passengers as far as possible to move in the right-hand direction, and it is also important to arrange the position and grouping of the ticket offices so that the line of passengers purchasing tickets will not be interfered with or crossed by passengers leaving the station or by those with tickets desirous of reaching the trains. Ticket offices for the sale of steam railroad tickets should be located in convenient sight of travelers, but entirely out of the stream of traffic, whereas for the sale of strip tickets, used in rapid transit service, the boxes must be located along the direct stream of movement, so that no passenger leaves his general direction, and yet so grouped that while one stream of persons is purchasing tickets, there is unobstructed

opportunity for those persons already having tickets to pass along. The arrangement of ticket windows in tandem on the same face is valueless, for the reason that those who are buying tickets at the first window must of necessity cross the stream of passengers trying to obtain tickets at the second window, which invariably causes discomfort and obstruction. The Hudson and Manhattan Railroad has carried out the usual arrangement of installing one large and important ticket office at a station in which the ticket agent can keep his safe, stock of tickets, and cash, and in addition has provided sundry portable ticket offices which can be wheeled into line during the busy hours and moved entirely out of the way during the slack hours. In all cases the arrangement of ticket offices should be such that the ticket-chopper is near to the ticket-seller, so that the seller may have the chopper under observation, and so that in case of necessity the ticket-chopper may assist the ticket-seller. However, the distance between the two should be such as to permit a passenger, after having purchased a ticket, to pause before putting the ticket into the chopping-box. One ticket-chopper usually serves two lines or streams of traffic, and the barriers should be only so wide as to allow a single file of passengers to pass on each side of the chopping-box. The most convenient and desirable width for this passage is 24 inches. With the ordinary stream of passengers on this road it is found that one ticket-chopper can pass through the gate in two files 108 passengers per minute. This rate of passage is too great, however, except for short spurts, as the chopper cannot properly examine tickets, and provision should be made for an average rate per chopper not exceeding 4000 persons per hour. An examiner who has to punch or personally scrutinize railroad tickets can only pass about 30 per minute. An ordinarily competent ticket agent will sell about 2000 rapid transit tickets per hour and make change, or for short periods may sell as many as 2500 tickets per hour. In calculating the number of selling agents or chopping-boxes necessary for handling the maximum traffic, these figures can be taken as a basis for speed.

In connection with the stations there is one other matter to which reference should be made: that is, the necessity for the use of elevators or escalators at certain points in the underground railroad where the depth of the station below the surface is considerable. The new plans of the Public Service Commission require them when the lift exceeds 30 feet. This is provided on the Hudson and Manhattan Railroad at the Pennsylvania station in Jersey City. The capacity

of an escalator is usually thought to be considerably greater than the capacity of an elevator, on account of an escalator taking a continuous stream of people and moving them as they arrive without an intermission or pause, which is of considerable importance; as a pause, however short in duration, affects materially the flow of passenger movement. The elevator service was installed at the Pennsylvania station, therefore, on account of the absolute necessities of the case, as it was impossible by any arrangement which could be devised to lay out an escalator service at that point, and the conditions were ideal for the installation of an elevator service. The company provided elevator service with the utmost appreciation of the possible congestion arising therefrom. The size of the elevators was limited by the width of panel in the main bracing of the elevated station and allowed cages only 10 feet square. Further, the Pennsylvania Railroad Company could not, without seriously affecting its own business, spare the concourse floor room sufficient for more than four elevators. The capacity of these elevators, on the basis of allowing two square feet per person, is 50 persons per lift, and as the lift of about 92 feet is continuous from bottom to top, and vice versâ, it was agreed to operate at the comparatively slow speed of 300 feet per minute, particularly as the actual running time of the elevators is small when compared with the total elevator interval. To facilitate the movement of passengers the scheme of dividing incoming and outgoing passengers, was used; the same as in the other stations. This was done by providing openings on the front and rear of the elevator cages, receiving passengers from the Pennsylvania Railroad trains direct into the elevators from the train side and discharging passengers from the tunnels to the Pennsylvania Railroad trains on the opposite side. The gates are as nearly the full width of the elevators themselves as they could be made. It was possible to get an effective gate opening of 6 feet 3½ inches in width, and to equip the elevators with a pneumatic device by which the elevator operator controls the opening and closing of the doors of the cages and elevator fronts. The result of the layout has thus far greatly exceeded the original idea of its possibilities, and has more than satisfied the officers of the Pennsylvania Railroad as to capacity. It is usually not desirable to attempt to fill the cages to their maximum capacity, and to handle passengers most efficiently and expeditiously it is found that a load of 40 persons will accomplish more than one of 50, on account of the delay in loading the additional 10 people. In this manner, the four

elevators can handle passengers at the rate of 60 people per minute in one direction. On one occasion five fully loaded suburban trains of the Pennsylvania Railroad, after being stalled at Point of Rocks outside Jersey City, came into the station practically in a procession, and the passengers moved into the elevators as they arrived without the slightest congestion or undue inconvenience. An elevator of the size installed at this station is probably more efficient for the rapid handling of passengers than one of larger floor space, as the service is so rapid that there is practically no pause in the flow of people.

Cars.—In handling passengers, the second important point is the design of car, particularly with reference to loading and unloading, and its internal arrangement as affecting the passenger, and its relation to the station. In the first place, the train service operated by the Hudson and Manhattan Railroad is essentially a short-distance service. The longest continuous distance usually traveled by a passenger—from Pennsylvania station to Thirty-third Street, or from Hoboken terminal to Church Street terminal—is less than four miles, consequently the time a passenger is in a car is comparatively short, and not comparable with the time taken on a railroad such as the electrified lines of the Long Island Railroad, or the Interborough Rapid Transit Subway, where a passenger may ride from 20 to 25 miles on a continuous trip. It is a well-known fact that a crowd of people desirous of traveling on a train will insist on using the first train in every case, and will jam itself into a train whether there is sitting room or not, notwithstanding that another train is following within ninety seconds, and in spite of the fact that crowding an already overloaded train materially lengthens the time of the station stops and interferes with the headway and progress of all following trains. The next following train may be running practically empty. It is, therefore, not essential on a road such as the Hudson and Manhattan, to attempt to provide the maximum seating capacity in a car, but it is necessary to give an adequate seating capacity only under ordinary conditions and at ordinary hours, and to give the greatest floor space, for standing room, and for carrying the maximum number of people in the easiest way with the least obstruction and inconvenience due to deliberate overcrowding.

The Hudson and Manhattan Railroad trains are essentially moving terminals for the steam railroads; a very large number of passengers carry valises and other baggage; consequently, the car with the

greatest unobstructed floor area is the most advantageous for such service. For this reason it is desirable to arrange the seats along the sides of the car without cross-seats, which possibly would have given but four or six seats additional per car, but which would have obstructed very materially the rapid movement of passengers. This arrangement gives a seating capacity of forty-four persons per car. A novel feature of this scheme for seating is the subdivision of seats into sections, which was devised by Mr. Stillwell. This scheme was adopted because most of the passengers desire corner seats, and for the purpose of stiffening the side trusses of the car. The subdivision of seats into sections is convenient and has proved to be very popular.

The use of the enameled rods in place of straps adds another convenience for passengers. Enameled rods are more sanitary than leather straps, and a new enameled metal loop is being tried by the Rapid Transit Subway as a substitute for leather straps.

The newspapers have so thoroughly educated the public as to the merits and demerits of side doors for cars that there is little to add here. Side doors were first used in a practical way on the Hudson and Manhattan road, and with complete success; but to get the maximum efficiency they should be used in conjunction with platforms at the level of the car floor and with station platforms arranged for loading passengers on one side and unloading on the opposite side. The cars have a clear opening of 36 inches for each end door and 41 inches for the side door. With these conditions 106 people can be unloaded in twenty-nine seconds, or at the rate of 3.65 per second, and there is not the necessity for the very wide doors which are essential where the loading and unloading is from the same side. The earlier cars of the Rapid Transit Subway were arranged with only end doors having an effective opening of about 33 inches. This is wider than is strictly necessary for a single line of passengers, but at the same time altogether too narrow for a double line. Cars more recently built and provided with side doors have an effective opening of 47 inches, which permits a double line of persons outward, or a single line of passengers moving out and a single line moving in at the same time; but even with these wide openings, the result is not as expeditious as with loading and unloading on opposite sides.

The installation and operation of side doors is complicated in opening and closing, as the side doors are necessarily out of sight of the guards standing at the end of the car, and the doors cannot conveniently be opened and closed by men on the platform. It

would be a very serious burden to maintain men on every platform to operate the side doors. On the Hudson and Manhattan Railroad all car doors are equipped with a pneumatic device for opening and closing, and there are air-cushions on the edges of the doors. No trouble whatsoever in the operation of the doors, and practically no accidents of a serious nature, have occurred. The Rapid Transit Subway has equipped the side doors of its newer cars with mechanical devices operating with a chain and toothed gears, which appear to operate satisfactorily.

Generally speaking, in rapid transit service the conditions are different from street railroad conditions by reason of the fact that on a street railroad passengers get on and off the cars and trains anywhere, and that fares are collected in each car at the point where a passenger gets on, which makes the entire distance the car travels practically a continuous station. In any rapid transit or high-speed line it is necessary to make definite stops at stations and to equip each station properly for the sale and collection of tickets instead of on the trains.

The greatest complication, in connection with a moving platform device, is in making it a continuous station. One of the points of advantage in a moving platform is the fact that the whole distance can be made a station, practically the condition on a street railway; but it is almost impossible to equip the whole length of the platform with ticket agents.

The capacity of trains is regulated, as before outlined, by the capacity of the cars forming the trains. The frequency is regulated by the time interval at which trains can be operated, and is irrespective of the speed of trains, which affects only the convenience of the public, and the ability of a railroad to get business. A railroad is a commercial enterprise, and while it is constructed for public service, it is primarily constructed with a view of obtaining an adequate return on the money invested. To obtain this result, therefore, on a private or public investment, it is essential to operate with the greatest efficiency, and to so design a railroad that it can give maximum service. Therefore the details presented here will indicate the importance of not sparing trouble or expense in designing, constructing, and equipping a railroad so as to give the greatest service with the least inconvenience to the traveling public combined with maximum efficiency and economical operation. The essential point with a public service corporation is to serve the public prop-

erly, and this was the underlying thought of Mr. McAdoo, the President, when at the opening of the Hudson and Manhattan Railroad he addressed the employees with words to the effect that he wanted no effort spared in the operation of the railroad to please the public.

If it is conceded that a rapid transit railroad is a public utility, then there is also implied a mutual obligation between those who operate the road, and the public authorities who grant franchises and regulate the service, to treat each other in a broad-minded manner, and to coöperate in providing rapid transit facilities which will be of the greatest service and convenience to the traveling public.

PAPER NO. 1092.

A TRIP ACROSS THE ISTHMUS: LIFE AND CONDITIONS ON THE CANAL ZONE.

MARTIN NIXON-MILLER.
(Active Member.)

Read April 30, 1910.

OF all the difficult engineering problems of the present day, there is not one on such a great scale as that of digging the canal across the Isthmus of Panama.

The scheme of the canal was first thought of by a Spanish engineer named Saavedra, in 1517, one of Balboa's followers. This was during the reign of Charles V, King of Spain. Surveys were ordered, but the work was reported impracticable. Philip II, successor to Charles V, in 1567 sent an engineer to survey the Nicaragua route, who also submitted an unfavorable report. Philip then laid the matter before the Dominican monks, who, desiring to obey the king's orders, but being unable to report intelligently, searched the Bible and quoted the following verse as having direct reference to the Isthmian Canal: "What God hath joined together, let no man put asunder" (St. Matthew xix : 6). This was sufficient for King Philip, and the subject was dropped for two centuries after his death. In 1814 Spain once more considered this question when her Central and South American colonies obtained their independence; and all that can be said of Spain now is that she furnishes some of the best laborers on the canal; one Spaniard being equal to three negroes, and less troublesome. The negroes are English subjects from the West Indies. American negroes from the southern states proved very unsatisfactory, and but few remain.

The French began the canal in 1878, but owing to their failure in making good sanitary conditions, they died by the thousand. The machinery used by the French was the best that could be bought at that time, and some of it is now used to advantage by the Americans, although in design, speed, and size of units it is far behind the present standards. The principal point of excellence of the French

machinery, which has weathered so well on the Isthmus for the past twenty-five years, is the quality of material and workmanship.

The French removed 69,000,000 cubic yards of material, but only 29,908,000 cubic yards will be of any use to the present canal, owing to changes to eliminate some curves, and putting in the dam at Gatun, instead of Bohio.

The Americans began work in 1904, and during the first three years, which may be called the period of preparation, the only tools available were some old French excavators, small locomotives, dump cars, and drills. In 1904, only 240,000 cubic yards were dug, 1,800,000 in 1905, and 5,000,000 in 1906. During this period modern American equipment, consisting of dredges, steam shovels, cars, locomotives, etc., were put into service as fast as could be purchased and hurried down to the Zone.

Sanitary Conditions.—The Americans first attended to making conditions such that their employees could live in comfort, as far as it was in man's power to do so in the tropics. They drained or filled up marshes, cut down the foliage along the line of the canal, built sewers and reservoirs, and threw plenty of oil around the mosquito districts. There are very few mosquitos now in the Zone district, yet they would come in fast from the jungle but for the fact that breeding-places are well sprinkled with oil. This sanitary work was originally and is still in charge of Colonel W. C. Gargas, U. S. A. He is also in charge of the hospitals.

During the improvement of sanitary conditions good living quarters with all modern improvements for the Americans were also built. The old French houses were used mostly for the foreign laborers. The hospitals are equal, if not superior, to any in the states. The one at Ancon has about 2500 beds, and the one at Colon has about 500 beds. In addition, there are emergency hospitals along the line in several of the larger towns.

The greatest amount of sickness is from malarial or Chágres fever, which is prevalent mostly among the negroes, who are usually extremely careless, often sleeping in their damp clothes. There is less fever now than when the mosquitos were on the Zone. The heavy night fogs are also conducive to malaria if one's system is run down.

Many men have been on the Zone for five and six years, yet have never been ill. This, it is believed, results from letting rum alone, for 80 per cent. of the American cases in the hospitals are men who drink more or less—usually more. Owing to the vigilance of the

Sanitary Department, sickness is kept very low, as well as the death-rate. The Department even takes care to catch mice and rats, as these animals carry the bubonic plague.

At present there is a total of 36,900 Government employees, 6000 being Americans, the remainder consisting of sixty-nine nationalities, of which 25,000 are negroes and 4000 are Spaniards. To January 1, 1910, there were but 12 deaths per 1000, while in 1906 the rate was 65, and in 1905 it was 45. Thus it can be seen how carefully the Sanitary Department, which includes the hospitals, does its share of hard work in this great canal enterprise. The usual number of sick is now only about 30 per 1000, of which 22 per 1000 are negroes.

Tobago Sanitarium, built by the French, is used for the American and Spanish employees when discharged from the hospital. The time spent there is usually a week to ten days, and it is in the most delightful location in the tropics, situated 12 miles off Panama. There is less rain there than in Ancon. The best pineapples in the world are raised there. The patients enjoy good sailing and bathing. The Government takes care of the employees free of cost.

There is not a case of yellow fever, smallpox, or bubonic plague on the Zone.

Temperature.—Although within but a few degrees of the equator, the conditions are entirely different from what most people expect, owing to the belt of aqueous vapor which hangs over the Isthmus and permeates the atmosphere. The humidity is nearly always over 85 per cent. This is a very disagreeable feature at first, but, after becoming acclimated, it is preferable to the heat which would otherwise be felt.

During the rainy and dry seasons there is usually a difference of 15 to 20 degrees between day and night. In the rainy season the variation is from 65 to 85 degrees, and that of the dry season from 75 to 95 degrees. Owing to this change in temperature, and to the thinning of one's blood, a blanket is a necessary article for the Americans, and sometimes more than one is needed in order to be comfortable.

Rainy Season.—Although but forty-seven miles across the Isthmus, most of the rain falls on the Atlantic side, graduating during the year 1909 from 237 inches at Cristobal to 84 inches at Ancon on the Pacific side. As a comparison, New York, Philadelphia, Boston, Portland, and St. Louis had 40 inches, San Francisco 23 inches, Denver 14 inches, and New Orleans, 60 inches. Thus it can be readily understood what a rain is in the tropics, when all the above rain on the

Zone fell during seven months, from the middle of May to the middle of December. There are often such heavy rains that an umbrella and an ordinary raincoat are useless, an oil skin being needed. It may be understood better by the fact that 6 inches have fallen during a period of one hour.

Dry Season.—After so much rain the dry season, which lasts for about five months, is looked forward to with delight. Because of the trade winds, the heat is not felt, although the temperature is from 75 to 95 degrees. But after the foliage dries up and the red bugs get active (to say nothing of the dust from the cut due to the trains, blasting, and travel on the roads, besides forest fires), the return of the rainy season is welcomed. Men working in the cut and sheltered from the trade winds get the full benefit of the sun, yet, notwithstanding that the temperature is 120 degrees Fahr., there is no record of any one in the Zone having had a sunstroke.

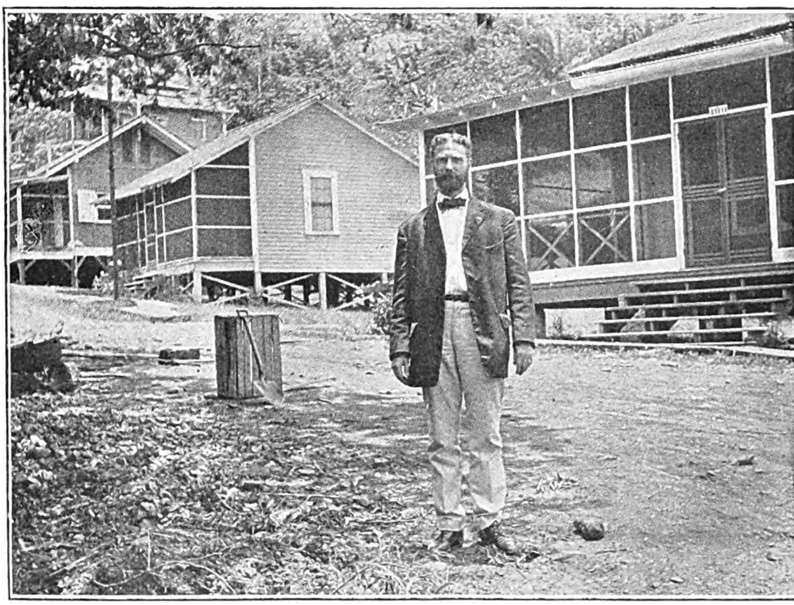
There being no railroad connections with the Zone, it is necessary to travel by boat from New Orleans, New York, or San Francisco, but this last route is not used by employees. Upon nearing the Isthmus, one first sees Porto Bello, twenty miles from Colon. As the American port at Cristobal is approached, the old De Lesseps Mansion and the historic Christ Church in Colon can be seen. The houses resemble huge bird-cages, with their surrounding porches screened in. The approach is most beautiful. The houses, usually painted white and green, and the tropical coloring of the flowers, orchids, and begonias, form vivid blots against the green of the royal palms, banana and cocoanut trees, and the wild tangle of jungle.

Before landing one has either to show a certificate of vaccination, made within the past six months, or be vaccinated. Then one is directed to the town, and, in turn, the district quartermaster assigns quarters.

The Zone is divided into the Atlantic, Central, and Pacific divisions. Culebra is the administration town, in which reside the chief engineer and chairman, Colonel George W. Goethals, with his assistants and designing engineers. Colonel H. F. Hodges is the assistant chief engineer in charge of the designing forces on locks and dams, and also acts in Colonel Goethals's place when the latter is not on the Zone. The divisions are in charge of the following: Atlantic, Colonel W. L. Seibert; Central, Colonel D. D. Gaillard; and Pacific, Mr. S. B. Williamson.

Colonel C. A. Devol is in charge of the Quartermaster Department, which has subdivisions for subsistence, commissary, labor, and quarters. The ice and cold storage plant is in this department, and is of ample capacity to take care of the employees. Eighty tons of ice are made daily and is sold to the employees at the rate of forty cents per 100 pounds. Bakeries and steam laundries are also in this department.

Government.—The Zone is conducted in a manner similar to that in the states, having its courts, hospitals, police and fire departments,



Types of houses furnished for men working on the Canal Zone.

churches, schools, Young Men's Christian Association, Red Cross Society, of which Colonel C. A. Devol is president, and the Salvation Army Association, which takes well with the negro. There are also various secret societies which do much good in charitable work.

Consideration for Employees.—First: An employee, upon reaching his destination, is provided with hotel and commissary coupon books, which pay for meals and commissary supplies (soap, towels, clothes, tobacco, etc.). In this way a man who arrives "dead broke" can live.

Second: Bills contracted for, must be paid, or the employee loses his position (gambling debts are excepted, but if an employee is known to be a gambler, he also loses his position).

Third: In bachelor quarters, with every convenience, it is necessary to buy only bed linens and towels, while in married quarters, dishes and cooking outfits must be bought in addition. However, the stove, wood, coal, lights, and good drinking-water are furnished free.

Fourth: Amusements, *i. e.*, minstrels, musicals, etc., are free. Every Sunday and holiday a good brass band, employed by the Government, gives a concert in one of the towns along the line.

Fifth: There are five Y. M. C. A. buildings, having bowling alleys, billiard and pool tables, shuffle-boards, gymnasiums, reading-rooms and a large circulating library. In addition, there is an entertainment hall with a stage. Dances are given twice a month by social clubs in this hall. The government, in getting the Y. M. C. A. to take up work on the Zone, made a reservation for two nights a month for the social clubs. Dancing is thoroughly enjoyed in the tropics. At Colon and Panama there is good surf bathing, but it has two disagreeable features—sharks and jelly-fish. The sting of the latter, though not deadly, will often make it necessary to stay a week in the hospital.

Sixth: Employees are allowed thirty days' sick leave per year, with pay, when ill through no fault of their own. All medical and surgical treatment is free. Venereal patients lose sick leave and have to pay for treatment. If not ill during the first twelve months, forty-five days' sick leave is allowed. The last and most important consideration is the annual vacation of forty-two days, with full pay. The rate of transportation to and from the Isthmus for those employed prior to January, 1909, is only $20 each way. Those entering the service after that date pay $30. If employed in the states, an employee is sent down at the Government's expense. The salaries are about 50 to 100 per cent. higher than for similar work in the states.

Why Consideration is Necessary.—To begin with, every man, woman, and child is subject to malarial or Chágres fever, with which some unfortunates suffer for the remainder of their lives.

The heavy night fogs, which penetrate the rooms like so much loose steam, cause all leather goods to mildew overnight, to say nothing of the mildewing of clothes, rusting of penknives, etc. It is most annoying to find one's shoes covered with mildew on rising in the morning.

Then, there is the little parasite known as the dhobie. This little fellow is invisible, and comes in one's laundry or shower-bath. He leaves his mud home to get under one's skin in the protected parts, and is the cause of an itch, known as the dhobie itch, to which every person is subject. Salicylic acid is the common remedy, but it causes the skin to parch, crack, and bleed. Maignen's antiseptic powder, manufactured by the Maignen Chemical Company, of Philadelphia, Pa., has been successfully used for relieving pain caused by dhobie itch, mosquito bites, ivy-poisoning, and jelly-fish stings.

Other annoying features are the red bugs, which bury themselves deeply under the skin and have to be dug out with the point of a knife, otherwise causing bad sores. In addition, there are the red and white ants, large flying roaches, beetles, sand-fleas, and sand-flies, to say nothing of the scorpions, tarantulas, and culebras. "Culebra" is the Spanish word for "snake." The most venomous is the coral snake. However, they are not often seen directly along the Canal, as all animal and reptile life has gone back to the jungle, owing to the noise from the train and blasting. The red ants are always busy doing good as scavengers, or else doing mischief by destroying plants and trees. It is because of these ants that vegetables, such as are raised in the states, are not cultivated on the Isthmus, except in a few places, where constant watching is required to make a success. This vigilance is too much for any native of Panama.

The white ant is very destructive, cutting its way into all kinds of wood, thus causing many a house to fall.

Food.—Food-stuffs are entirely cold storage and canned goods. Native fruits are not appreciated at first, except the oranges, bananas, pineapples, and grape fruit. The papias, mangos, alligator pears, and about half a dozen other fruits are sadly missed upon returning to the states.

Fresh meats can be bought, but a sight of the slaughter-house, the men handling the meat, and the dirty Spanish markets is sufficient inducement to let it alone.

Game.—Lots of fine sport may be had hunting deer, alligators, tigers or wildcats, and turkeys, but in this sport a nasty jungle must be traversed, stirring up snakes, scorpions, tarantulas, red bugs, and mosquitos. Upon returning from a hunt many a strong man has been taken with the Chágres fever, as a result of having been bitten by the mosquitos, which disease he might otherwise have escaped.

Canal Dimensions.—The Canal, or "Ditch," as it is more commonly called on the Zone, will be 49¾ miles long, deep water to deep water, with a width varying from 300 to 1000 feet, and a depth from 45 to 75 feet. It is two-thirds finished in length, there being several miles where only the tops of the hills had to be cut down, as the lake formed by the dams at Gatun and Pedro Miguel covers the natural surface.

Lock System.—The judgment used in selecting the lock system, time has proved to be the best. To the layman, and even to engineers, the task of digging a sea-level canal looks gigantic but simple. The nine miles through the Culebra cut would be an easy task, but for twenty-five miles from Gatun to Bas Obispo, through the swamps and along the course of the lower Chágres River, the difficulties encountered would be almost insurmountable. How much material would flow into the cut from the sides? It can well be imagined what the condition would be if dug below the level of the surrounding country, and much of the way through soft quagmires. In various parts of the Zone the earth looks as if some one had gone over the place with a great plow, the strata not being the same for a distance of fifty feet. The rain so soaks this ground that it becomes like molasses, and then slides into the cut. Therefore, the advantages of the lock system are: First, the amount of excavation is enormously reduced, and the cost and time correspondingly diminished, even with the cost of locks and dams included. Second, the ease with which the floods of the Chágres and other rivers will be controlled by the Gatun Lake. Third, a large portion of silt and gravel would otherwise be carried down and deposited in the canal, to say nothing of great slides which would take place and thus require a large force of men constantly at work. Fourth, drains, or diversions, as they are called, allow the men to work where they otherwise would be flooded out. Even as it is now, there sometimes will be a week's rain, which stops the work. Fifth, the great value to a vessel in killing the marine growths by the fresh water of Gatun Lake.

Earthquakes of a severe nature may visit Panama at any time, as well as any other region of the globe. But it is to be remembered that in the sea-level canal a great dam would be needed at Gamboa, and a rupture of this dam would wipe out all the canal from Gamboa to the Atlantic. However, no danger of a severe shock is anticipated, as it is above and below the line of volcanic disturbances.

Unstable pieces of masonry have been standing in Panama since the eighteenth century.

There is a place over which the dam at Gatun is built that has over 100 feet in depth of bad material. This is being displaced by rock piles and old French iron rails that gradually sink to hard pan. It was a portion of this bad material which sank about thirty feet in a few hours, November 23, 1909, and an irresponsible newspaper reporter, not seeing or understanding conditions, by cabling to the states that the great Gatun Dam had sunk, was the cause of many unfavorable comments being published. In view of the fact that the Government employs the best engineers, both military and civil, and that the whole undertaking is well managed, it would be well for the critics to let the subject alone until the great Canal is finished.

The digging, although done under very trying conditions, owing to the seven months of rain and the annoyance of the insects during the dry season, is progressing very rapidly. It is now done at the rate of 35,000,000 cubic yards per year.

The work is being done along the entire length of the Canal, and is divided into three classes: First, wet excavation, by dredges, which amounts to 73,000,000 cubic yards = 12 per cent.; second, dry excavation, by steam shovels, 93,000,000 cubic yards for the Canal, and for locks and extras due to slides, 9,000,000 cubic yards = 49 per cent.; third, construction of locks, dams, and spillways = 39 per cent.

Up to January 1, 1910, 95,000,000 cubic yards had been excavated, leaving 80,000,000 cubic yards to be moved. At the present rate of progress the Canal will be finished in 1913 at the latest. If all the concrete work, installation of locks, gates, and operating machinery can be placed, within the time of excavation, the Canal will be opened two years earlier than scheduled. About 53 per cent. of the total work is done.

Breakwater.—This is necessary on the Atlantic side, opposite Colon, for, during the autumn months storms from the north occur, locally called "northers." These storms are of such violence that all vessels have to go for protection to the harbor at Porto Bello. The Pacific side never has storms of sufficient violence and duration to require special protection. On account of the cross-currents in the channel on the Pacific side, where the tides rise and fall from 20 to 22 feet in twelve hours, a dike is being built from Balboa to Naos Island, four miles from shore. This will prevent the silt from settling

in the canal channel, as the set of the current is at right angles to the entrance of the channel, close to the shore. The building of this dike provides a place for disposing of the material from the cut south of Empire. North of Empire this material is used at Gatun Dam.

Gatun Dam.—No dam ever built has received more attention from the world at large than this one, principally because of its size. It is built between the hills of Gatun, through which the famous Chágres River flows to the sea. It consists of a core confined by rock walls. The core is composed of clay and sand mixed and deposited hydraulically. The dam rests on impermeable material of sufficient supporting power. It is 7500 feet long over all, measured on its crest, only 500 feet being subject to the pressure of 85 feet of water, and 3000 feet subject to the pressure of 50 feet of water. The width of the dam at the base is about 2000 feet, and the core at the base is about 860 feet. At the crest of the dam it will be 400 feet, and the height of the dam above the lake will be 30 feet with a width of 100 feet.

The locks are located at the east end of the dam in rock excavation. The usable length of each lock will be 1000 feet by 110 feet wide and 45 feet deep. There is a flight of three locks in pairs at Gatun, and the rise will be 85 feet above sea-level. There is one pair of locks at Pedro Miguel and a flight of two locks at Miraflores in pairs.

The culverts in the lock walls are 18 feet in diameter, and it is estimated that the time of filling the lock will be a little over eight minutes, or a rise of over 3 feet per minute. In ordinary operation the rate would be 2 feet per minute, or about fifteen minutes to fill the lock.

Concrete Work for Gatun.—The cement is brought from the United States, the rock from Porto Bello, and the sand from old Nombre de Dios, beyond. Sand for the concrete for the Pacific locks is from the peninsula of Chamè, west of Panama. Rock is from the west side of Ancon hill. Concrete lining for the Canal is only in a portion of Culebra cut, under water, and not, as many people suppose, the full length of the canal.

The gates for the locks are 7 feet thick, 65 feet long, and from 47 to 82 feet high. They weigh from 400 to 800 tons each. Eighty-four are required for the entire canal, the total weight being 58,000 tons. The locks are divided into 650 and 350 feet chambers, as 95 per cent. of vessels are less than 600 feet long. Thus, water can be saved in the dry season. At the end of the rainy season the lake will be at

87 feet level, to allow extra storage for the dry season. Absorption amounts to about $\frac{1}{7}$ inch per day, or 50 inches per year.

The tonnage passing through the Suez Canal is about 21,000,000 gross tons per year, at Sault Ste. Marie 40,000,000, and the Panama Canal is amply big enough to take care of 80,000,000.

The lock will be filled through lateral culverts in the floor, currents and eddies being reduced to a minimum when the lock is filled or emptied quickly.

The locks are the largest ever designed, and have the following safety arrangements:

First, two barriers separating the high level from that next below, *i. e.*, there are double gates each at the lower and upper end of the top locks, the double gates being worked simultaneously.

Second, a chain, resisting 220,000 pounds per square inch, stretched across, and so arranged near the surface of the water as to stop a 10,000-ton vessel moving at a speed of six miles per hour, or a 30,000-ton vessel moving at two miles per hour.

Third, an emergency dam in the form of swing drawbridge, from which six pairs of heavy wicket (box) girders are let down in pairs. The bridge supports one end, and a sill in the bottom of the canal supports the other end. Five heavy steel box slabs are then lowered successively on each pair of girders. Thus, the area of the water is diminished gradually. This movable dam is above the upper locks.

Fourth, vessels will not be permitted to enter the lock with their propellers in motion. A team of four electric mules will draw the vessels.

The emergency dam will be operated by electric motors, and will be able to stop the flow in about half an hour.

The dam at Pedro Miguel is 1400 feet long, against a 40-foot head. At Miraflores it is 2800 feet long, with a spillway similar to that at Gatun. Power plants will be at Gatun and Miraflores, each consisting of three 1500 Kw. turbine generators and six 400 HP boilers. The spillway at Gatun is placed on a hill of rock in the center of the dam. It has a concrete-lined opening, and is supplied with gates suitable in design to allow the lake level to be regulated. The spillway at Miraflores is similar. The spillway at Gatun is 300 feet wide, and is designed to run off 140,000 cubic feet per second. The capacity of the Miraflores spillway is 39,000 cubic feet per second.

The Chágres River, which is 300 feet wide and 2 feet deep in dry season, will rise to 40 feet in twenty-four hours. This will affect the

rise in the Gatun Lake only 2 feet. Gatun Lake covers an area of 165 square miles. From Gatun to Pedro Miguel it is 32 miles. In the first 8 miles no digging is necessary; trees and underbrush only have been removed. At Bohio a few high points have been leveled off. For the first 15 miles from Gatun the channel is 1000 feet wide; from Tabernilla it is 800 feet for 4 miles, and thence to Bas Obispo it is 500 feet for 4 miles. Many million cubic yards excavated by the French between Tabernilla and Bas Obispo saved the Americans that much work, but that done by the French between the Atlantic Ocean and Tabernilla is not useful.

The Chágres River crosses the Canal not less than fifteen times between Tabernilla and Bas Obispo. At the latter town it turns abruptly northeast, and the Canal enters the 9-mile cut through the Cordilleras mountains known as the "Culebra Cut." For these 9 miles it is 300 feet wide to Pedro Miguel locks. Here, through one lock, Miraflores Lake is reached. This lake covers about two square miles, and is kept full from the Rio Grande and Cocoli Rivers, and also from water entering with vessels from the Pedro Miguel lock. From here it is eight miles to the Pacific entrance. It is estimated that most vessels can travel from deep water to deep water in twelve hours.

Landslides.—In order to give some idea of the vast landslides, the one at Cucaracha, just south of Gold Hill, is the best known, as it was a source of annoyance to the French in 1884. At that time it was 800 feet in length and covered 6 acres. It is now nearly 2 miles long and covers 30 acres. About 1,000,000 cubic yards are in motion. In 1907 it moved 14 feet in twenty-four hours, and overturned a steam shovel, while burying another. One hundred and fifteen thousand cubic yards moved into and across the cut with a glacier-like motion, completely filling it up for the time being. The French spent thousands of dollars for elaborate drainage systems, which proved inadequate. The only remedy is to remove the material. While important in themselves, these slides will not cost over one per cent. of the total amount of the digging. Tropical vegetation will undoubtedly cover the banks before the canal is completed, and thus hold them in place. However, the hill on which Culebra is built will cause considerable trouble in the near future by sliding into the cut. This will be worse than the Cucaracha slide, and time will show that this prediction is correct.

Method of Excaavtion.—The various excavation operations are

successively as follows: drilling, blasting, loading, transporting, and dumping.

Tripod drills are used for shallow holes, well or churn drills are used for deeper holes, and hand drilling for a few isolated holes. Compressed air furnishes the power for the drills, at 80 pounds pressure. A 10-inch air main runs the full length of the cut at Culebra, with an extension at the south end to Miraflores. Pressure is equalized by compression at these points. Each plant has six compressors of a capacity of 2500 cubic feet to 100 pounds pressure per minute.

Each shovel is preceded by a battery of from four to twelve drills, covering a field 30 to 40 feet wide, which keeps well ahead of the shovel. Holes are drilled from 15 to 30 feet deep, and from 6 to 16 feet apart, depending upon the material and conditions. Each hole is loaded with a charge of from 75 to 200 pounds of dynamite, 45 and 60 per cent. dynamite being used principally. Five hundred tons are used monthly. After being loaded, the holes are connected in parallel, and discharged by electric current.

Accidents have happened, but those killed have been mostly alien laborers. The worst accident happened in December, 1909, which resulted in fifty deaths, most of them laborers. It was at Bas Obispo, where 22 tons of dynamite in 53 holes prematurely exploded. The theory was that the water in the holes, being slightly acid, tended to liberate the nitroglycerin, which, being in an extremely unstable condition, exploded from some small shock or vibration due possibly to a distant shot or blast. The electrician was also killed. Some of these holes had been loaded several days before the explosion. Now, no holes are loaded that cannot be fired on the same day.

The 75-ton steam shovels have a 2½-yard dipper and the 95-ton shovels have a 4- to 5-yard dipper. They are self-propelling, and able to make a cut over 20 feet deep. There are over one hundred shovels at work. In working down from one level to the next lower level, it is customary to start shovels at different points to dig the center trench, called the "pilot cut," 34 feet wide at the bottom, 50 feet at the top, and from 15 to 20 feet deep. These pilot shovels are followed up by shovels widening the cut on each side, each taking a width of 26½ feet. Notwithstanding repairs, accidents, and delays in moving shovels forward, they work at least three-quarters of the time, and, owing to the excellent management of the railroad, very little time is lost in waiting for cars.

The material is loaded into cars, each car holding about 20 cubic yards. There are nineteen cars to a train, and it takes only about one hour to load the entire train. Each shovel loads from four to six trains per day. The material per train is from 500 to 600 tons. From Empire, the dirt trains move down-grade, south to Miraflores or Balboa (La Boca) dumps; from Empire, north down-grade to Gatun Dam and Panama Railroad relocation.

The Panama Railroad, although controlled by the United States Government, is a separate organization from the Canal. Of the total number of Government employees, 7700 are with this railroad. At Empire there are large repair shops for steam-shovels, employing 600 men. At Gorgona large shops, employing 1000 men, are used for locomotives, cars, and equipment other than steam-shovels. At these shops are iron and brass foundries.

The work requiring the largest number of laborers is in moving and ballasting tracks. In Culebra Cut alone there are about 75 miles of track, and in the whole central division 200 miles of track, exclusive of the double track of the Panama Railroad. Over a mile of track is moved per day in the Culebra Cut. In moving tracks on the dumps, a track shifter is used, which performs the work of 500 laborers.

Costs.—The average cost to the French amounted to about $4.00 per cubic yard, while the American costs vary in accordance with material and length of haul to dumping grounds, from 10 cents to $1.00 per cubic yard. The French received from the United States $40,000,000, which was ample from a conservative estimate, as follows:

29,908,000 cubic yards material removed	$27,500,000
Panama Railroad, franchise, all rights, etc.	7,000,000
Drawings, maps, and technical data	2,000,000
Buildings and machinery	3,500,000

About 43,000 acres of land went with the Panama Railroad property and 33,000 acres were acquired from the French Canal Company.

In consideration of the $10,000,000 paid to Panama for the rights conveyed, there was turned over to the United States, in addition, all public lands in the Canal Zone, amounting to 120,000 acres. This makes the United States Government the direct owner of 70 per cent. of the land in the Canal Zone, the remaining 30 per cent. being held by private citizens of Panama. The United States exercises governmental control over all.

The Panama government receives a royalty of $250,000 per year when the Canal is completed.

The Act of Congress of 1902 placed the entire jurisdiction in regard to the construction of the Canal in the hands of the President of the United States, the particular functions in regard thereto being exercised by a commission composed of seven members appointed in accordance with the Act of Congress, and presided over by one member as chairman.

For convenience of administration, the Canal operations have been placed under the Secretary of War.

The cost of the Canal completed will very nearly be $400,000,000. This is more than was estimated at first, and includes, first, excavation; second, concrete for locks, spillways, and part of Culebra Cut; third, embankment and fills for dams and breakwaters; fourth and fifth, Departments of Sanitation and Civil Administration; sixth, price paid the French Canal Company and that paid the Panama government.

The increase of the estimate from $222,000,000 in 1905 to the above is due mainly to such causes as working eight hours, instead of the customary ten hours, upon which the unit costs of the estimates were based; to the higher wages and special inducements, such as six weeks' annual vacation, thirty days' sick leave, family dwellings of a degree of comfort never before attempted in a construction camp; to the scarcity of skilled labor and the boom of prices prevailing in the United States during the organization of this work; to the fact that surveys and borings on the new features were far from complete at the time of the estimate; and, beyond all this, to the many unforeseen items of extra cost attendant on carrying on so great a work in the tropics, many hundreds of miles away from the base of supplies. Causes that have increased the cost of the lock canal would have increased the cost of similar items in a sea-level canal in the same proportion, while in the features of flood control for the sea-level project, the uncertainties of surveys were much greater.

In one very important feature, that of progress, the canal is being built inside the estimate, and for this, all the engineers and men along the line should receive highest praise. They show a spirit of earnestness, confidence, and co-operation, and a general wholesomeness of life, which make of this narrow 47-mile strip the best and greatest construction camp the world has ever seen, and one of which every American should be proud.

The working hours are every week-day from 7 A. M. to 5 P. M., with two hours at noon for rest. There are no half holidays, only Sundays and legal holidays for rest.

The meals are the only item of cost in living. There are three meals furnished per day to the negro at 30 cents, to the Spaniard at 40 cents, and to the American at 90 cents. Having to pay only for meals, clothing, and laundry, it is possible to save as much in one year on the Zone as would take several years in the States.

IN MEMORIAM.*

LIEUTENANT-COLONEL SILAS GILDERSLEEVE COMFORT.

DIED JULY 13, 1910.

Lieutenant-Colonel Silas Gildersleeve Comfort was born at Triangle, Broome County, New York, April 27, 1863. His forefathers settled in New Jersey in Colonial times, and came of an old and distinguished English family. His great-grandfather, Richard Comfort, fought in the Revolution, and his grandfather, John Comfort, was a prominent merchant and built the Delaware-Susquehanna division of the National Road between the Hudson River and Lake Erie, afterward the route of the Erie Railroad. His father, Rev. Dr. Silas Comfort, was a minister of the Methodist Episcopal Church.

Both his parents died while he was a child, and he lived in the family of his half-brother, George Fisk Comfort, an eminent scholar, art critic, and author, who founded the College of Fine Arts at Syracuse University and acted as its dean for twenty years. This opened up unusual opportunities for education, as his half-brother, who was thirty years his senior, treated him as a son, gave him every advantage of the private and public schools in Syracuse, and afterward entered him at Syracuse University.

Here he took the course in civil engineering and also that in architecture, studying six years in all, and earning the degrees of Bachelor in Civil Engineering and Bachelor in Architecture. Later he received from Syracuse University (1887) the first Master's degree in Architecture ever given in America. While in college he was a charter member of the Sigma Psi Society, which later became the Syracuse chapter of the Phi Delta Theta fraternity.

During his college vacations Colonel Comfort was in charge of construction work on the then new West Shore Railroad between Utica and Savannah, N. Y., and was also employed at times by the Phœnix Iron Company at Phœnixville, Pa. He was an enthusiastic student of structural steel engineering, and the practical experience thus gained during undergraduate years was of great advantage to him.

* Prepared by St. George H. Cooke and Thomas C. McBride.

Upon graduation from Syracuse University in 1884, Colonel Comfort became an instructor in mathematics and technical drawing in the Pennsylvania Military College (then the Pennsylvania Military Academy) at Chester. In 1889 he was advanced to the professorship of Architecture and made an instructor in civil engineering. In 1889 the college in which he was teaching conferred upon him the degree of Civil Engineer, and three years afterward he was made Professor of Engineering and Astronomy and appointed Captain and Adjutant of the college. Three years after that he was made Vice-President of the college and was commissioned a Lieutenant-Colonel by the State of Pennsylvania.

His career as a teacher in the Pennsylvania Military College covered twenty-six years. During this time he did much outside work in his profession, one of his most notable commissions being the designing of the steel work in the Yale University Library. He received, the day before his death, the appointment as Consulting Engineer of the City of Chester, his special duty being the supervision of the expenditure of the city loan, involving work estimated at over a million and a half dollars.

Colonel Comfort was a Mason, an Associate American Society of Civil Engineers, a member of the Penn Club of Chester and of the American Geographical Society. He served upon the school board of Chester and was president of the board of trustees of the Third Presbyterian Church of that city. He became a member of the Engineers' Club of Philadelphia in October, 1892, and was made a director, 1901 and 1904; vice-president, 1902-03; and president, 1905.

During his long career as a teacher and during his membership of the Engineers' Club, Colonel Comfort was held in high esteem and regard by all who knew him. At the Pennsylvania Military College he was popular among the students and remembered with respect by the graduates, which is the highest tribute a teacher may gain. His faithful attendance at board meetings of the Engineers' Club and the accuracy and care with which he edited the proceedings of this society during three years were matters of comment.

Colonel Comfort is survived by his widow, who was Helen de Lannoy, and two children, Martha, aged seventeen, and Frederick, aged fourteen years; also by a sister, Grace M. Comfort, of New York city, and a half-brother, Melville Lane Comfort, of Monroe, Michigan.

ABSTRACT OF MINUTES OF THE BOARD OF DIRECTORS.

ADJOURNED MEETING, July 14, 1910.—Present: President Easby, Vice-Presidents Christie, Hewitt, Directors Ehlers, Cochrane, Plack, Halstead, Wilson, Worley, the Secretary, and the Treasurer.

The Secretary reported that, in accordance with the By-Laws, the following had been dropped for non-payment of dues: E. E. Bratton, C. F. Chambers, W. H. Hansell, F. N. Price, J. Herbert Schall, and S. K. Thompson.

Bernard Sullivan was reinstated as an Active Member, provided his delinquent dues were paid in full.

The following resignations were accepted as of June 30, 1910: Active, Harry B. Hirsh, S. W. Kapp, Calvin P. Bascom, C. W. Palmer, and Chas. S. Churchill; Junior, Charles T. Myers and Wilson S. Yerger.

The death of Professor Silas G. Comfort was announced, and it was ordered that Thomas C. McBride and St. George H. Cooke be appointed to prepare a memorial for publication in the "Proceedings."

Upon recommendation of the Secretary, the salary of the stenographer was increased from $12 to $15 per week.

The President and Treasurer were authorized to negotiate a note, in amount not exceeding $2500, to liquidate the floating indebtedness.

The Committee on House reported that it had decided to appoint the present steward as general house steward, in charge of all the physical property of the Club. A new set of house rules, proposed by the Committee on House, was formally ratified.

The Committee on Loan for the improvement of the Club-house reported that a loan of $8500 on a long-term note secured by individual indorsements could not be obtained from any of the trust companies, but reported that it could raise this money on a number of individual notes.

Subsequent to this report, it was ordered that the following extract from the minutes of the regular meeting of the Board held May 19, 1910, be rescinded:

"It was also ordered that the Board authorize the immediate obtaining of a loan of $8500 on a note secured by individual indorsements."

It was then moved and carried that the method of securing $8500, as recommended by the Committee on Loan, be approved, and that the President and Treasurer be authorized to execute a number of individual notes for a term of one year, with the privilege of renewal, bearing interest at five per cent., and aggregating an amount not exceeding $8500.

It was then ordered that the Committee on Loan be continued as a Building Committee.

REGULAR MEETING, September 16, 1910.—Present: President Easby, Directors Ehlers, Cochrane, Develin, Plack, Swaab, Mebus, Wood, Halstead, Worley

and the Secretary. The minutes of the regular meeting of May 19th and of the adjourned meetings of June 9th and July 14th were read and approved.

The following resignations were accepted as of July 1, 1910: Active Members, Joseph Upton, Paul W. England, and Gilbert S. Smith; Associate, Joseph Van d. Titus.

The Secretary announced the deaths of Washington Jones, George W. Hayes, and William D. Beatty.

The matter of the contract with the accountant, Charles W. Todd, was discussed, and the Secretary was authorized to extend this contract, if possible, for a period of three months.

The Committee on Increase of Membership, appointed October 25, 1909, was discharged with thanks, and it was ordered that a new Committee on Increase of Membership be appointed by the chair.

On recommendation of the Committee on House, the holding of a Smoker during the latter part of October was authorized.

The Committee on Revision of the By-Laws, appointed June 9th, presented its report, and following this, the Board recommended that the proposed amendments be brought before the Club for action.